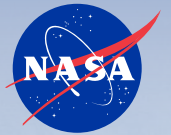


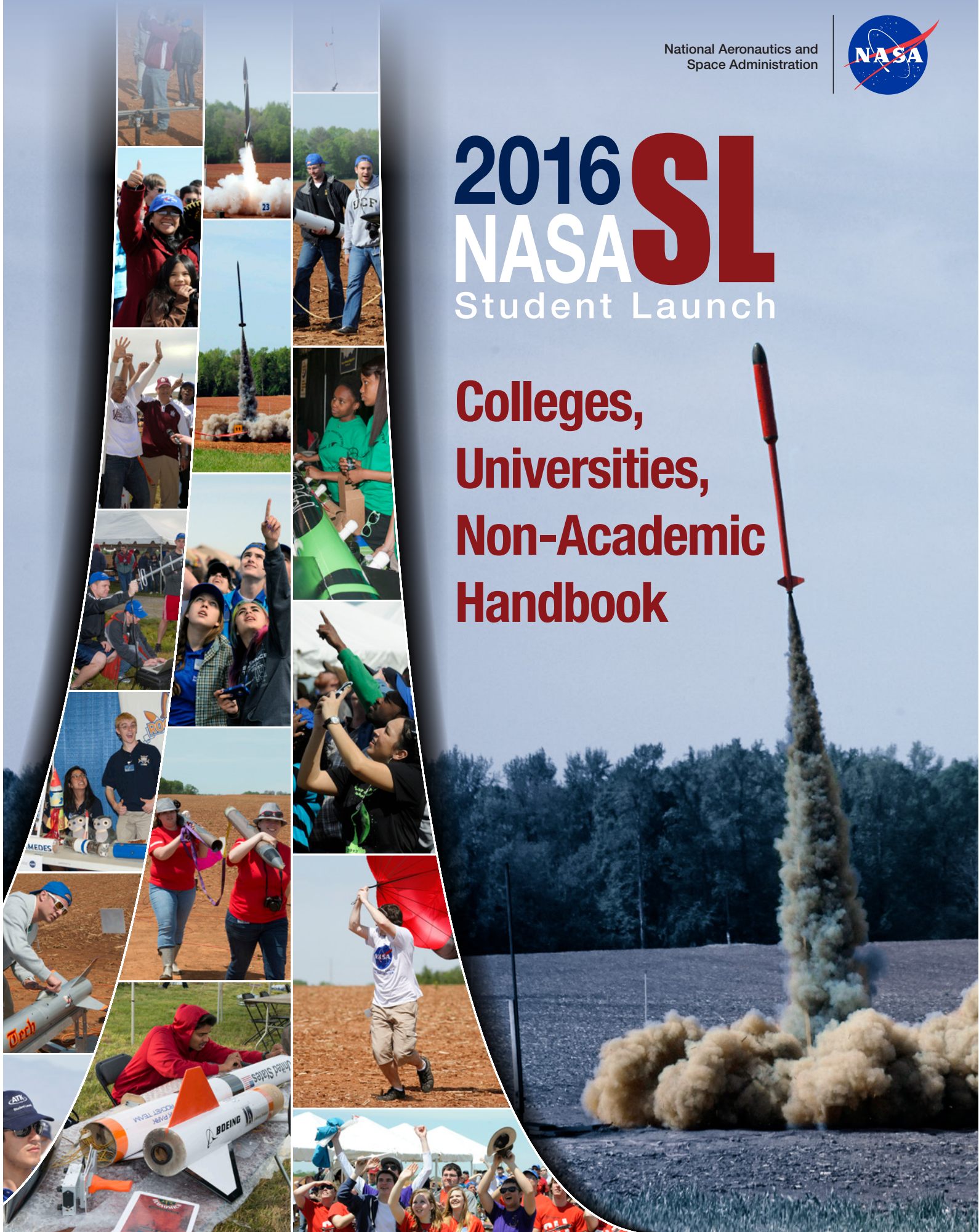
National Aeronautics and  
Space Administration



# 2016 NASA SL

Student Launch

## Colleges, Universities, Non-Academic Handbook



**Note:** For your convenience, this document identifies Web links when available. These links are correct as of this publishing; however, since Web links can be moved or disconnected at any time, we have also provided source information as available to assist you in locating the information.

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# Timeline for NASA University Student Launch Initiative

(Dates are subject to change.)

## August 2015

- 7 Request for Proposal (RFP) goes out to all teams.

## September 2015

- 11 Electronic copy of completed proposal due to project office by 5 p.m. CDT to  
  
Ian Bryant (Jacobs ESSSA Group) [ian.i.bryant@nasa.gov](mailto:ian.i.bryant@nasa.gov)  
  
Katie Wallace: [katie.v.wallace@nasa.gov](mailto:katie.v.wallace@nasa.gov)  
  
Julie Clift: [julie.d.clift@nasa.gov](mailto:julie.d.clift@nasa.gov)

## October 2015

- 2 Awarded proposals announced
- 7 Kickoff and PDR Q&A
- 23 Team web presence established

## November 2015

- 6 Preliminary Design Review (PDR) reports, presentation slides, and flysheet posted on the team Website by 8:00 a.m. Central Time.
- 9-20 PDR video teleconferences

## December 2015:

- 4 CDR Q&A

## January 2016:

- 15 Critical Design Review (CDR) reports, presentation slides, and flysheet posted on the team Website by 8:00 a.m. Central Time.
- 19-29 CDR video teleconferences

## February 2016:

- 3 FRR Q&A

## March 2016:

- 14 Flight Readiness Review (FRR) reports, presentation slides, and flysheet posted to team Website by 8:00 a.m. Central Time.
- 17-30 FRR video teleconferences

## April 2016:

- 13 Teams travel to Huntsville, AL
- 13 Launch Readiness Reviews (LRR)
- 14 LRR's and safety briefing
- 15 Rocket Fair and Tours of MSFC
- 16 Launch Day
- 17 Backup launch day
- 29 Post-Launch Assessment Review (PLAR) posted on the team Website by 8:00 a.m. Central Time.

## May 2016:

- 11 Winning team announced



# Acronym Dictionary

AGL=Above Ground Level  
APCP=Ammonium Perchlorate Composite Propellant  
CDR=Critical Design Review  
CC=Centennial Challenges  
CG=Center of Gravity  
CP=Center of Pressure  
EIT=Electronics and Information Technology  
FAA=Federal Aviation Administration  
FN=Foreign National  
FRR=Flight Readiness Review  
HEO=Human Exploration and Operations  
LCO=Launch Control Officer  
LRR=Launch Readiness Review  
MAV=Mars Ascent Vehicle  
MSDS=Material Safety Data Sheet  
MSFC=Marshall Space Flight Center  
NAR=National Association of Rocketry  
PDR=Preliminary Design Review  
PLAR=Post Launch Assessment Review  
PPE=Personal Protective Equipment  
RFP=Request for Proposal  
RSO=Range Safety Officer  
USLI=University Student Launch Initiative  
SME=Subject Matter Expert  
SOW=Statement of Work  
STEM=Science, Technology, Engineering, and Mathematics  
TRA=Tripoli Rocketry Association

# Proposal/Statement of Work for Colleges/ Universities/Non-Academic Teams



# **Design, Development, and Launch of a Reusable Rocket and Autonomous Ground Support Equipment Statement of Work (SOW)**

- 1. Project Name: NASA University Student Launch Initiative for colleges and universities**
- 2. Governing Office: NASA Marshall Space Flight Center Academic Affairs Office**
- 3. Period of Performance: Eight (8) calendar months**

## **4. Introduction**

The NASA University Student Launch Initiative (USLI) is a research-based, competitive, and experiential exploration project that provides relevant and cost effective research and development. Additionally, NASA University Student Launch Initiative connects learners, educators, and communities in NASA-unique opportunities that align with STEM Challenges under the NASA Education Science, Technology, Engineering, and Mathematics (STEM) Engagement line of business. NASA's missions, discoveries, and assets provide opportunities for individuals that do not exist elsewhere. The project involves reaching a broad audience of colleges and universities, across the nation in an 8-month commitment to design, build, launch, and fly a payload(s) and vehicle components that support NASA research on high-power rockets to an altitude of 5,280 feet above ground level (AGL). The challenge is based on team selection of multiple options. There is a Student Launch option that consists of 7 different experiments, and a Centennial Challenge (CC) option that consists of designing and building a Mars Ascent Vehicle (MAV). Supported by the Office of Education, Human Exploration and Operations (HEO) Mission Directorate, Centennial Challenges Office, and commercial industry, USLI is a unique, NASA-specific opportunity to provide resources and experiences that is built around a mission, not textbook knowledge.

After a competitive proposal selection process, teams participate in a series of design reviews that are submitted to NASA via a team-developed website. These reviews mirror the NASA engineering design lifecycle, providing a NASA-unique experience that prepares individuals for the HEO workforce. Teams must successfully complete a Preliminary Design Review (PDR), Critical Design Review (CDR), Flight Readiness Review (FRR), Launch Readiness Review (LRR) that includes safety briefings, and an analysis of vehicle systems, ground support equipment, and flight data. Each team must pass a review in order to move to a subsequent review. Teams will present their PDR, CDR, and FRR to a review panel of scientists, engineers, technicians, and educators via video teleconference. Review panel members, the Range Safety Officer (RSO), and Subject Matter Experts (SME) provide feedback and ask questions in order to increase the fidelity between the USLI and research needs, and will score each team according to a standard scoring rubric. The partnership of teams and NASA is win-win, which not only benefits from the research conducted by the teams, but also prepares a potential future workforce familiar with the NASA Engineering Design Lifecycle.

College and university teams must successfully complete the requirements of Tasks 1 or 2, and are eligible for awards through Student Launch. Any team who wishes to incorporate additional research through the use of a separate payload may do so. The team must provide documentation in all reports and reviews on components and systems outside of what is required for the project. The Centennial Challenges Office will award prizes to college, university and non-academic teams for successful demonstration of the MAV (see CC supplemental handbook). The USLI awards listed at the end of this handbook will only be given to teams from an academic institution.



## 1. Vehicle Requirements

- 1.1. The vehicle shall deliver the payload to an apogee altitude of 5,280 feet above ground level (AGL).
- 1.2. The vehicle shall carry one commercially available, barometric altimeter for recording the official altitude used in the competition scoring. The altitude score will account for 10% of the team's overall competition score. Teams will receive the maximum number of altitude points (5,280) if the official scoring altimeter reads a value of exactly 5,280 feet AGL. The team will lose two points for every foot above the required altitude, and one point for every foot below the required altitude. The altitude score will be equivalent to the percentage of altitude points remaining after any deductions.
  - 1.2.1. The official scoring altimeter shall report the official competition altitude via a series of beeps to be checked after the competition flight.
  - 1.2.2. Teams may have additional altimeters to control vehicle electronics and payload experiment(s).
    - 1.2.2.1. At the Launch Readiness Review, a NASA official will mark the altimeter that will be used for the official scoring.
    - 1.2.2.2. At the launch field, a NASA official will obtain the altitude by listening to the audible beeps reported by the official competition, marked altimeter.
    - 1.2.2.3. At the launch field, to aid in determination of the vehicle's apogee, all audible electronics, except for the official altitude-determining altimeter shall be capable of being turned off.
  - 1.2.3. The following circumstances will warrant a score of zero for the altitude portion of the competition:
    - 1.2.3.1. The official, marked altimeter is damaged and/or does not report an altitude via a series of beeps after the team's competition flight.
    - 1.2.3.2. The team does not report to the NASA official designated to record the altitude with their official, marked altimeter on the day of the launch.
    - 1.2.3.3. The altimeter reports an apogee altitude over 5,600 feet AGL.
    - 1.2.3.4. The rocket is not flown at the competition launch site.
- 1.3. The launch vehicle shall be designed to be recoverable and reusable. Reusable is defined as being able to launch again on the same day without repairs or modifications.
- 1.4. The launch vehicle shall have a maximum of four (4) independent sections. An independent section is defined as a section that is either tethered to the main vehicle or is recovered separately from the main vehicle using its own parachute.
- 1.5. The launch vehicle shall be limited to a single stage.
- 1.6. The launch vehicle shall be capable of being prepared for flight at the launch site within 2 hours, from the time the Federal Aviation Administration flight waiver opens.
- 1.7. The launch vehicle shall be capable of remaining in launch-ready configuration at the pad for a minimum of 1 hour without losing the functionality of any critical on-board component.
- 1.8. The launch vehicle shall be capable of being launched by a standard 12 volt direct current firing system. The firing system will be provided by the NASA-designated Range Services Provider.
- 1.9. The launch vehicle shall use a commercially available solid motor propulsion system using ammonium perchlorate composite propellant (APCP) which is approved and certified by the National Association of Rocketry (NAR), Tripoli Rocketry Association (TRA), and/or the Canadian Association of Rocketry (CAR).
  - 1.9.1. Final motor choices must be made by the Critical Design Review (CDR).
  - 1.9.2. Any motor changes after CDR must be approved by the NASA Range Safety Officer (RSO), and will only be approved if the change is for the sole purpose of increasing the safety margin.
- 1.10. The total impulse provided by a launch vehicle shall not exceed 5,120 Newton-seconds (L-class).
- 1.11. Pressure vessels on the vehicle shall be approved by the RSO and shall meet the following criteria:
  - 1.11.1. The minimum factor of safety (Burst or Ultimate pressure versus Max Expected Operating Pressure) shall be 4:1 with supporting design documentation included in all milestone reviews.
  - 1.11.2. Each pressure vessel shall include a pressure relief valve that sees the full pressure of the tank.

- 1.11.3. Full pedigree of the tank shall be described, including the application for which the tank was designed, and the history of the tank, including the number of pressure cycles put on the tank, by whom, and when.
- 1.12. All teams shall successfully launch and recover a subscale model of their full-scale rocket prior to CDR. The subscale model should resemble and perform as similarly as possible to the full-scale model, however, the full-scale shall not be used as the subscale model.
- 1.13. All teams shall successfully launch and recover their full-scale rocket prior to FRR in its final flight configuration. The rocket flown at FRR must be the same rocket to be flown on launch day. The purpose of the full-scale demonstration flight is to demonstrate the launch vehicle's stability, structural integrity, recovery systems, and the team's ability to prepare the launch vehicle for flight. A successful flight is defined as a launch in which all hardware is functioning properly (i.e. drogue chute at apogee, main chute at a lower altitude, functioning tracking devices, etc.). The following criteria must be met during the full scale demonstration flight:
  - 1.13.1. The vehicle and recovery system shall have functioned as designed.
  - 1.13.2. The payload does not have to be flown during the full-scale test flight. The following requirements still apply:
    - 1.13.2.1. If the payload is not flown, mass simulators shall be used to simulate the payload mass.
    - 1.13.2.2. The mass simulators shall be located in the same approximate location on the rocket as the missing payload mass.
    - 1.13.2.3. If the payload changes the external surfaces of the rocket (such as with camera housings or external probes) or manages the total energy of the vehicle, those systems shall be active during the full-scale demonstration flight.
  - 1.13.3. The full-scale motor does not have to be flown during the full-scale test flight. However, it is recommended that the full-scale motor be used to demonstrate full flight readiness and altitude verification. If the full-scale motor is not flown during the full-scale flight, it is desired that the motor simulate, as closely as possible, the predicted maximum velocity and maximum acceleration of the competition flight.
  - 1.13.4. The vehicle shall be flown in its fully ballasted configuration during the full-scale test flight. Fully ballasted refers to the same amount of ballast that will be flown during the competition flight.
  - 1.13.5. After successfully completing the full-scale demonstration flight, the launch vehicle or any of its components shall not be modified without the concurrence of the NASA Range Safety Officer (RSO).
- 1.14. Each team will have a maximum budget of \$7,500 they may spend on the rocket and its payload(s). (Exception: Centennial Challenge payload task. See supplemental requirements at: <http://www.nasa.gov/mavprize> for more information). The cost is for the competition rocket and payload as it sits on the pad, including all purchased components. The fair market value of all donated items or materials shall be included in the cost analysis. The following items may be omitted from the total cost of the vehicle:
  - Shipping costs
  - Team labor costs

### 1.15. Vehicle Prohibitions

- 1.15.1. The launch vehicle shall not utilize forward canards.
- 1.15.2. The launch vehicle shall not utilize forward firing motors.
- 1.15.3. The launch vehicle shall not utilize motors that expel titanium sponges (Sparky, Skidmark, MetalStorm, etc.).
- 1.15.4. The launch vehicle shall not utilize hybrid motors.
- 1.15.5. The launch vehicle shall not utilize a cluster of motors.

## 2. Recovery System Requirements

- 2.1. The launch vehicle shall stage the deployment of its recovery devices, where a drogue parachute is deployed at apogee and a main parachute is deployed at a much lower altitude. Tumble recovery or streamer recovery from apogee to main parachute deployment is also permissible, provided the kinetic energy during drogue-stage descent is reasonable, as deemed by the Range Safety Officer.
- 2.2. Teams must perform a successful ground ejection test for both the drogue and main parachutes. This must be done prior to the initial subscale and full scale launches.
- 2.3. At landing, each independent section of the launch vehicle shall have a maximum kinetic energy of 75 ft-lbf.
- 2.4. The recovery system electrical circuits shall be completely independent of any payload electrical circuits.
- 2.5. The recovery system shall contain redundant, commercially available altimeters. The term "altimeters" includes both simple altimeters and more sophisticated flight computers. One of these altimeters may be chosen as the competition altimeter.
- 2.6. Motor ejection is not a permissible form of primary or secondary deployment. An electronic form of deployment **must** be used for deployment purposes.
- 2.7. A dedicated arming switch shall arm each altimeter, which is accessible from the exterior of the rocket airframe when the rocket is in the launch configuration on the launch pad.
- 2.8. Each altimeter shall have a dedicated power supply.
- 2.9. Each arming switch shall be capable of being locked in the ON position for launch.
- 2.10. Removable shear pins shall be used for both the main parachute compartment and the drogue parachute compartment.
- 2.11. An electronic tracking device shall be installed in the launch vehicle and shall transmit the position of the tethered vehicle or any independent section to a ground receiver.
  - 2.11.1. Any rocket section, or payload component, which lands untethered to the launch vehicle shall also carry an active electronic tracking device.
  - 2.11.2. The electronic tracking device shall be fully functional during the official flight at the competition launch site.

2.12. The recovery system electronics shall not be adversely affected by any other on-board electronic devices during flight (from launch until landing).

2.12.1. The recovery system altimeters shall be physically located in a separate compartment within the vehicle from any other radio frequency transmitting device and/or magnetic wave producing device.

2.12.2. The recovery system electronics shall be shielded from all onboard transmitting devices, to avoid inadvertent excitation of the recovery system electronics.

2.12.3. The recovery system electronics shall be shielded from all onboard devices which may generate magnetic waves (such as generators, solenoid valves, and Tesla coils) to avoid inadvertent excitation of the recovery system.

2.12.4. The recovery system electronics shall be shielded from any other onboard devices which may adversely affect the proper operation of the recovery system electronics.

### 3. Competition and Payload Requirements

Each team shall choose any 2 payloads from Task 1, or have the choice to participate in the Centennial Challenge competition (Task 2).

Task 1 (select any 2)		Task 2
3.1.1	Atmospheric Measurements	3.1.8 Centennial Challenge – MAV
3.1.2	Landing Hazards Detection	
3.1.3	Liquid Sloshing in Micro-G	
3.1.4	Propulsion System Analysis	
3.1.5	Payload Fairing Design and Deployment	
3.1.6	Aerodynamic Analysis	
3.1.7	Design your own (limit of one)	

3.1. The payload shall be designed to be recoverable and reusable. Reusable is defined as being able to be launched again on the same day without repairs or modifications.

3.2. (Task1) The team may choose to participate in 2 of the following payload options.

3.2.1. A payload that shall gather data for studying the atmosphere during descent and after landing, including measurements of pressure, temperature, relative humidity, solar irradiance and ultraviolet radiation.

3.2.1.1. Measurements shall be made at least once every second during descent, and every 60 seconds after landing. Data collection shall terminate 10 minutes after landing.

3.2.1.2. The payload shall take at least 2 pictures during descent, and 3 after landing. The payload shall remain in orientation during descent and after landing such that the pictures taken portray the sky towards the top of the frame and the ground towards the bottom of the frame.

3.2.1.3. The data from the payload shall be stored onboard and transmitted wirelessly to the team's ground station at the time of completion of all surface operations.

3.2.2. A payload that scans the surface continuously during descent in order to detect potential landing hazards.

3.2.2.1. The data from the hazard detection camera shall be analyzed in real time by a custom designed on-board software package that shall determine if landing hazards are present.

3.2.2.2. The data collected shall be stored on board and transmitted wirelessly to the team's ground station.

3.2.3. Liquid sloshing research in microgravity to support liquid propulsion systems.



- 3.2.4. Structural and dynamic analysis of airframe, propulsion, and electrical systems during boost.
  - 3.2.4.1. The team must use an array of electrical sensors to measure structural vibration and to measure the stress and strain of the rocket in the axial and radial directions.
  - 3.2.4.2. At a minimum, structural analysis shall be performed on the fins/fin joints, all separation points, and the nose cone.
- 3.2.5. A payload fairing design and deployment mechanism.
  - 3.2.5.1. The fairings and payload must be tethered to the main body to prevent small objects from getting lost in the field.
- 3.2.6. An aerodynamic analysis of structural protuberances.
- 3.2.7. Design your own payload (limit of 1). Must be approved by NASA review team.

### 3.3. (Task 2) Centennial Challenge

**NASA University Student Launch Initiative is collaborating with the NASA Centennial Challenges Mars Ascent Vehicle (MAV) Project to offer teams the chance to design and build autonomous ground support equipment (AGSE). The Centennial Challenges Program, part of NASA's Science and Technology Mission Directorate, awards incentive prizes to generate revolutionary solutions to problems of interest to NASA and the nation. The goal of the MAV and its AGSE is to capture a simulated Martian payload sample, seal it within a launch vehicle, and prepare the vehicle for launch without the input from a human operator. For specific rules regarding the MAV project, and to learn more about Centennial Challenges, please visit the Centennial Challenge website at <http://www.nasa.gov/mavprize> and review their project handbook. NOTE: The Centennial Challenge handbook is meant to be a complement to this handbook. If a team chooses to participate in the Centennial Challenge, they must abide by all the rules presented in this document.**

## 4. Safety Requirements

- 4.1. Each team shall use a launch and safety checklist. The final checklists shall be included in the FRR report and used during the Launch Readiness Review (LRR) and launch day operations.
- 4.2. For all academic institution teams, a student safety officer shall be identified, and shall be responsible for all items in section 4.3. For competing, non-academic teams, one participant who is not serving in the team mentor role shall serve as the designated safety officer.
- 4.3. The role and responsibilities of each safety officer shall include but not limited to:
  - 4.3.1. Monitor team activities with an emphasis on Safety during:
    - 4.3.1.1. Design of vehicle and launcher
    - 4.3.1.2. Construction of vehicle and launcher
    - 4.3.1.3. Assembly of vehicle and launcher
    - 4.3.1.4. Ground testing of vehicle and launcher
    - 4.3.1.5. Sub-scale launch test(s)
    - 4.3.1.6. Full-scale launch test(s)
    - 4.3.1.7. Competition launch
    - 4.3.1.8. Recovery activities
    - 4.3.1.9. Educational Engagement activities
  - 4.3.2. Implement procedures developed by the team for construction, assembly, launch, and recovery activities.
  - 4.3.3. Manage and maintain current revisions of the team's hazard analyses, failure modes analyses, procedures, and MSDS/chemical inventory data.
  - 4.3.4. Assist in the writing and development of the team's hazard analyses, failure modes analyses, and procedures.

- 4.4. Each team shall identify a “mentor.” A mentor is defined as an adult who is included as a team member, who will be supporting the team (or multiple teams) throughout the project year, and may or may not be affiliated with the school, institution, or organization. The mentor shall be certified by the National Association of Rocketry (NAR) or Tripoli Rocketry Association (TRA) for the motor impulse of the launch vehicle, and the rocketeer shall have flown and successfully recovered (using electronic, staged recovery) a minimum of 2 flights in this or a higher impulse class, prior to PDR. The mentor is designated as the individual owner of the rocket for liability purposes and must travel with the team to the launch at the competition launch site. One travel stipend will be provided per mentor regardless of the number of teams he or she supports. The stipend will only be provided if the team passes FRR and the team and mentor attend launch week in April.
- 4.5. During test flights, teams shall abide by the rules and guidance of the local rocketry club’s RSO. The allowance of certain vehicle configurations and/or payloads at the NASA University Student Launch Initiative competition launch does not give explicit or implicit authority for teams to fly those certain vehicle configurations and/or payloads at other club launches. Teams should communicate their intentions to the local club’s President or Prefect and RSO before attending any NAR or TRA launch.
- 4.6. Teams shall abide by all rules and regulations set forth by the FAA.

## **5. General Requirements**

- 5.1. Team members (students if the team is from an academic institution) shall do 100% of the project, including design, construction, written reports, presentations, and flight preparation. The one exception deals with the handling of black powder, ejection charges, and installing electric matches. These tasks shall be performed by the team’s mentor, regardless if the team is from an academic institution or not.
- 5.2. The team shall provide and maintain a project plan to include, but not limited to the following items: project milestones, budget and community support, checklists, personnel assigned, educational engagement events, and risks and mitigations.
- 5.3. Each team shall successfully complete and pass a review in order to move onto the next phase of the competition.
- 5.4. Foreign National (FN) team members shall be identified by the Preliminary Design Review (PDR) and may or may not have access to certain activities during launch week due to security restrictions. In addition, FN’s will be separated from their team during these activities. If participating in the MAV task, less than 50% of the team make-up may be foreign nationals.
- 5.5. The team shall identify all team members attending launch week activities by the Critical Design Review (CDR). Team members shall include:
- 5.5.1. Students actively engaged in the project throughout the entirety of the project lifespan and currently enrolled in the proposing institution.
  - 5.5.2. One mentor (see requirement 4.4).
  - 5.5.3. No more than two adult educators per academic team.
- 5.6. The team shall engage a minimum of 200 participants in educational, hands-on science, technology, engineering, and mathematics (STEM) activities, as defined in the Educational Engagement form, by FRR. An educational engagement form shall be completed and submitted within two weeks after completion of each event. A sample of the educational engagement form can be found in the handbook.
- 5.7. The team shall develop and host a Website for project documentation.

- 5.8. Teams shall post, and make available for download, the required deliverables to the team Web site by the due dates specified in the project timeline.
- 5.9. All deliverables must be in PDF format.
- 5.10. In every report, teams shall provide a table of contents including major sections and their respective sub-sections.
- 5.11. In every report, the team shall include the page number at the bottom of the page.
- 5.12. The team shall provide any computer equipment necessary to perform a video teleconference with the review board. This includes, but not limited to, computer system, video camera, speaker telephone, and a broadband Internet connection. If possible, the team shall refrain from use of cellular phones as a means of speakerphone capability.
- 5.13. Teams must implement the Architectural and Transportation Barriers Compliance Board Electronic and Information Technology (EIT) Accessibility Standards (36 CFR Part 1194) Subpart B-Technical Standards (<http://www.section508.gov>):
- 1194.21 Software applications and operating systems.
  - 1194.22 Web-based intranet and Internet information and applications.

# Proposal Requirements

**At a minimum, the proposing team shall identify the following in a written proposal due to NASA MSFC by the dates specified in the project timeline.**

## **General Information**

1. A cover page that includes the name of the college/university or non-academic organization, mailing address, title of the project, the date, and which payload option(s) the team is participating in.
2. Name, title, and contact information for up to two adult educators (for academic teams).
3. Name and title of the individual who will take responsibility for implementation of the safety plan. (Safety Officer)
4. Name, title, and contact information for the team leader.
5. Approximate number of participants who will be committed to the project and their proposed duties. Include an outline of the project organization that identifies the key managers (participants and/or educator administrators) and the key technical personnel. Only use first names for identifying team members; do not include surnames. (See requirement 5.4 and 5.5 for definition of team members).
6. Name of the NAR/TRA section(s) the team is planning to work with for purposes of mentoring, review of designs and documentation, and/or launch assistance.

## **Facilities/Equipment**

1. Description of facilities and hours of accessibility, necessary personnel, equipment, and supplies that are required to design and build a rocket and the payload.

## **Safety**

The Federal Aviation Administration (FAA) [[www.faa.gov](http://www.faa.gov)] has specific laws governing the use of airspace. A demonstration of the understanding and intent to abide by the applicable federal laws (especially as related to the use of airspace at the launch sites and the use of combustible/ flammable material), safety codes, guidelines, and procedures for building, testing, and flying large model rockets is crucial. The procedures and safety regulations of the NAR [<http://www.nar.org/safety.html>] shall be used for flight design and operations. The NAR/TRA mentor and Safety Officer shall oversee launch operations and motor handling.

1. Provide a written safety plan addressing the safety of the materials used, facilities involved, and team member responsible, i.e., Safety Officer, for ensuring that the plan is followed. A risk assessment should be done for all aspects in addition to proposed mitigations. Identification of risks to the successful completion of the project should be included.
  - 1.1. Provide a description of the procedures for NAR/TRA personnel to perform. Ensure the following:
    - Compliance with NAR high power safety code requirements [<http://nar.org/NARhpsc.html>].
    - Performance of all hazardous materials handling and hazardous operations.
  - 1.2. Describe the plan for briefing team members on hazard recognition and accident avoidance, and conducting pre-launch briefings.
  - 1.3. Describe methods to include necessary caution statements in plans, procedures and other working documents, including the use of proper Personal Protective Equipment (PPE).



- 1.4. Provide a plan for complying with federal, state, and local laws regarding unmanned rocket launches and motor handling. Specifically, regarding the use of airspace, Federal Aviation Regulations 14 CFR, Subchapter F, Part 101, Subpart C; Amateur Rockets, Code of Federal Regulation 27 Part 55: Commerce in Explosives; and fire prevention, NFPA 1127 “Code for High Power Rocket Motors.”
- 1.5. Provide a plan for NRA/TRA mentor purchase, storage, transport, and use of rocket motors and energetic devices.
- 1.6. Provide a written statement that all team members understand and will abide by the following safety regulations:
  - 1.6.1. Range safety inspections of each rocket before it is flown. Each team shall comply with the determination of the safety inspection or may be removed from the program.
  - 1.6.2. The RSO has the final say on all rocket safety issues. Therefore, the RSO has the right to deny the launch of any rocket for safety reasons.
  - 1.6.3. Any team that does not comply with the safety requirements will not be allowed to launch their rocket.

### **Technical Design**

1. A proposed and detailed approach to rocket and payload design.
  - a. Include general vehicle dimensions, material selection and justification, and construction methods.
  - b. Include projected altitude and describe how it was calculated.
  - c. Include projected parachute system design.
  - d. Include projected motor brand and designation.
  - e. Include description of the team’s projected payload.
  - f. Address the requirements for the vehicle, recovery system, and payload.
  - g. Address major technical challenges and solutions.

### **Educational Engagement**

1. Include plans and evaluation criteria for required educational engagement activities. (See requirement 5.5).

### **Project Plan**

1. Provide a detailed development schedule/timeline covering all aspects necessary to successfully complete the project.
2. Provide a detailed budget to cover all aspects necessary to successfully complete the project including team travel to launch week.
3. Provide a detailed funding plan.
4. Provide a written plan for soliciting additional “community support,” which could include, but is not limited to, expertise needed, additional equipment/supplies, sponsorship, services (such as free shipping for launch vehicle components, if required, advertisement of the event, etc.), or partnering with industry or other public or private schools.
5. Develop a clear plan for sustainability of the rocket project in the local area. This plan should include how to provide and maintain established partnerships and regularly engage successive teams in rocketry. It should also include partners (industry/community), recruitment of team members, funding sustainability, and educational engagement.

**Prior to award, all proposing entities may be required to brief NASA representatives. The NASA MSFC Academic Affairs Office will determine the time and the place for the briefings.**

**Deliverables shall include:**

1. A reusable rocket and required payload ready for the official launch.
2. A scale model of the rocket design with a payload prototype. This model should be flown prior to the CDR. A report of the data from the flight and the model should be brought to the CDR.
3. Reports, PDF slideshows, and Milestone Review Flysheets due according to the provided timeline, and shall be posted on the team Web site by the due date. (Dates are tentative at this point. Final dates will be announced at the time of award.)
4. The team(s) shall have a Web presence no later than the date specified. The Web site shall be maintained/updated throughout the period of performance.
5. Electronic copies of the Educational Engagement form(s) and lessons learned pertaining to the implemented educational engagement activities shall be submitted prior to the FRR and no later than two weeks after the educational engagement event.

The team shall participate in a PDR, CDR, FRR, LRR, and PLAR. (Dates are tentative and subject to change.)

The PDR, CDR, FRR, and LRR will be presented to NASA at a time and/or location to be determined by NASA MSFC Academic Affairs Office.

# Vehicle/Payload Criteria



# **Preliminary Design Review (PDR)**

## **Vehicle and Payload Experiment Criteria**

The PDR demonstrates that the overall preliminary design meets all requirements with acceptable risk, and within the cost and schedule constraints, and establishes the basis for proceeding with detailed design. It shows that the correct design options have been selected, interfaces have been identified, and verification methods have been described. Full baseline cost and schedules, as well as all risk assessment, management systems, and metrics, are presented.

The panel will be expecting a professional and polished report. It is advised to follow the order of sections as they appear below.

### **Preliminary Design Review Report**

**All information contained in the general information section of the project proposal shall also be included in the PDR Report.**

#### ***I) Summary of PDR report (1 page maximum)***

##### **Team Summary**

- Team name and mailing address
- Name of mentor, NAR/TRA number and certification level

##### **Launch Vehicle Summary**

- Size and mass
- Motor choice
- Recovery system
- Milestone Review Flysheet

##### **Payload Summary**

- Payload title
- Summarize payload experiment

#### ***II) Changes made since Proposal (1-2 pages maximum)***

**Highlight all changes made since the proposal and the reason for those changes.**

- Changes made to vehicle criteria
- Changes made to payload criteria
- Changes made to project plan

#### ***III) Vehicle Criteria***

##### **Selection, Design, and Verification of Launch Vehicle**

- Include a mission statement, requirements, and mission success criteria.
- Review the design at a system level, going through each system's functional requirements (includes sketches of options, selection rationale, selected concept, and characteristics).
- Describe the subsystems that are required to accomplish the overall mission.
- Describe the performance characteristics for the system and subsystems and determine the evaluation and verification metrics.



- Describe the verification plan and its status. At a minimum, a table should be included that lists each requirement (in SOW), and for each requirement briefly describe the design feature that will satisfy that requirement and how that requirement will ultimately be verified (such as by inspection, analysis, and/or test).
- Define the risks (time, resource, budget, scope/functionality, etc.) associated with the project. Assign a likelihood and impact value to each risk. Keep this part simple i.e. low, medium, high likelihood, and low, medium, high impact. Develop mitigation techniques for each risk. Start with the risks with higher likelihood and impact, and work down from there. If possible, quantify the mitigation and impact. For example; including extra hardware to increase safety will have a quantifiable impact on budget. Including this information in a table is highly encouraged.
- Demonstrate an understanding of all components needed to complete the project and how risks/delays impact the project.
- Demonstrate planning of manufacturing, verification, integration, and operations (include component testing, functional testing, or static testing).
- Describe the confidence and maturity of design.
- Include a dimensional drawing of entire assembly. The drawing set should include drawings of the entire launch vehicle, compartments within the launch vehicle (such as parachute bays, payload bays, and electronics bays), and significant structural design features of the launch vehicle (such as fins and bulkheads).
- Include electrical schematics for the recovery system.
- Include a Mass Statement. Discuss the estimated mass of the launch vehicle, its subsystems, and components. What is the basis of the mass estimate and how accurate is it? Discuss how much margin there is before the vehicle becomes too heavy to launch with the identified propulsion system. Are you holding any mass in reserve (i.e., are you planning for any mass growth as the design matures)? If so, how much? As a point of reference, a reasonable rule of thumb is that the mass of a new product will grow between 25 and 33% between PDR and the delivery of the final product.

### **Recovery Subsystem**

- Demonstrate that analysis has begun to determine expected mass of launch vehicle and parachute size, attachment scheme, deployment process, and test results/plans with ejection charges and electronics.
- Discuss the major components of the recovery system (such as the parachutes, parachute harnesses, attachment hardware, and bulkheads), and verify that they will be robust enough to withstand the expected loads.

### **Mission Performance Predictions**

- State mission performance criteria.
- Show flight profile simulations, altitude predictions with simulated vehicle data, component weights, and simulated motor thrust curve, and verify that they are robust enough to withstand the expected loads.
- Show stability margin, simulated Center of Pressure (CP)/Center of Gravity (CG) relationship and locations.
- Calculate the kinetic energy at landing for each independent and tethered section of the launch vehicle.
- Calculate the drift for each independent section of the launch vehicle from the launch pad for five different cases: no wind, 5-mph wind, 10-mph wind, 15-mph wind, and 20-mph wind. The drift calculations should be performed with the assumption that the rocket will be launched in the same direction as the wind.

## **Interfaces and Integration**

- Describe payload integration plan with an understanding that the payload must be co-developed with the vehicle, be compatible with stresses placed on the vehicle, and integrate easily and simply.
- Describe the interfaces that are internal to the launch vehicle, such as between compartments and subsystems of the launch vehicle.
- Describe the interfaces between the launch vehicle and the ground (mechanical, electrical, and/or wireless/transmitting).
- Describe the interfaces between the launch vehicle and the ground launch system.

## **Safety**

- Develop a preliminary checklist of final assembly and launch procedures.
- Identify a safety officer for your team.
- Provide a preliminary Hazard analysis, including hazards to personnel. Also, include the failure modes of the proposed design of the rocket, payload integration, and launch operations. Include proposed mitigations to all hazards (and verifications if any are implemented yet). Rank the risk of each Hazard for both likelihood and severity.
  - Include data indicating that the hazards have been researched (especially personnel). Examples: NAR regulations, operator's manuals, MSDS, etc.
- Discuss any environmental concerns.
  - This should include how the vehicle affects the environment, and how the environment can affect the vehicle.

## ***IV) Payload Criteria***

### **Selection, Design, and Verification of payload**

- Review the design at a system level, going through each system's functional requirements (includes sketches of options, selection rationale, selected concept, and characteristics).
- Describe the payload subsystems that are required to accomplish the mission objectives.
- Describe the performance characteristics for the system and subsystems and determine the evaluation and verification metrics.
- Describe the verification plan and its status. At a minimum, a table should be included that lists each payload requirement and for each requirement briefly describe the design feature that will satisfy that requirement and how that requirement will ultimately be verified (such as by inspection, analysis, and/or test).
- Describe preliminary integration plan.
- Determine the precision of instrumentation, repeatability of measurement, and recovery system.
- Include drawings and electrical schematics for the key elements of the payload.
- Discuss the key components of the payload and how they will work together to achieve the desired mission objectives

### **Payload Concept Features and Definition**

- Creativity and originality
- Uniqueness or significance
- Suitable level of challenge

### **Science Value**

- Describe payload objectives.
- State the payload success criteria.
- Describe the experimental logic, approach, and method of investigation.
- Describe test and measurement, variables, and controls.

- Show relevance of expected data and accuracy/error analysis.
- Describe the preliminary experiment process procedures.

## ***V) Project Plan***

### **Show status of activities and schedule**

- Budget plan (in as much detail as possible)
- Funding plan
- Timeline (in as much detail as possible). GANTT charts are encouraged with a discussion and indication of the critical path. The critical path is the sequence of events that must be completed before the next phase of the project can begin.
- Educational engagement plan and status

## ***VI) Conclusion***

# **Preliminary Design Review Presentation**

Please include the following in your presentation:

- Vehicle dimensions, materials, and justifications
- Static stability margin
- Plan for vehicle safety verification and testing
- Baseline motor selection and justification
- Thrust-to-weight ratio and rail exit velocity
- Launch vehicle verification and test plan overview
- Drawing/Discussion of each major component and subsystem, especially the recovery subsystem
- Baseline Payload design
- Payload verification and test plan overview

The PDR will be presented to a panel that may be comprised of any combination of scientists, engineers, safety experts, education specialists, and industry partners. This review should be viewed as the opportunity to convince the NASA Review Panel that the preliminary design will meet all requirements, has a high probability of meeting the mission objectives, and can be safely constructed, tested, launched, and recovered. Upon successful completion of the PDR, the team is given the authority to proceed into the final design phase of the life cycle that will culminate in the Critical Design Review.

It is expected that the **team participants** deliver the report and answer all questions. The mentor shall only provide support in the presentation.

The presentation of the PDR shall be well prepared with a professional overall appearance. This includes, but is not limited to, the following: easy-to-see slides; appropriate placement of pictures, graphs, and videos; professional appearance of the presenters; speaking clearly and loudly; looking into the camera; referring to the slides, not reading them; and communicating to the panel in an appropriate and professional manner. The slides should use dark text on a light background.

# **Critical Design Review (CDR)**

## **Vehicle and Payload Experiment Criteria**

The CDR demonstrates that the maturity of the design is appropriate to support proceeding to full-scale fabrication, assembly, integration, and test that the technical effort is on track to complete the flight and ground system development and mission operations in order to meet overall performance requirements within the identified cost schedule constraints. Progress against management plans, budget, and schedule, as well as risk assessment, are presented. The CDR is a review of the final design of the launch vehicle and payload system. All analyses should be complete and some critical testing should be complete. The CDR Report and Presentation should be independent of the PDR Report and Presentation. However, the CDR Report and Presentation may have the same basic content and structure as the PDR documents, but with final design information that may or may not have changed since PDR. Although there should be discussion of subscale models, the CDR documents are to primarily discuss the final design of the full-scale launch vehicle and subsystems.

The panel will be expecting a professional and polished report. It is advised to follow the order of sections as they appear below.

### **Critical Design Review Report**

**All information included in the general information sections of the project proposal and PDR shall be included.**

#### ***I) Summary of CDR report (1 page maximum)***

##### **Team Summary**

- Team name and mailing address
- Name of mentor, NAR/TRA number and certification level

##### **Launch Vehicle Summary**

- Size and mass
- Motor choice
- Recovery system
- Rail size
- Milestone Review Flysheet

##### **Payload Summary**

- Payload title
- Summarize experiment

#### ***II) Changes made since PDR (1-2 pages maximum)***

**Highlight all changes made since PDR and the reason for those changes.**

- Changes made to vehicle criteria
- Changes made to Payload criteria
- Changes made to project plan



### **III) Vehicle Criteria**

#### **Design and Verification of Launch Vehicle**

##### **Flight Reliability and Confidence**

- Include mission statement, requirements, and mission success criteria
- Include major milestone schedule (project initiation, design, manufacturing, verification, operations, and major reviews)
- Review the design at a system level
  - Final drawings and specifications
  - Final analysis and model results, anchored to test data
  - Test description and results
  - Final motor selection
- Demonstrate that the design can meet all system level functional requirements. For each requirement, state the design feature that satisfies that requirement and how that requirement has been, or will be, verified.
- Specify approach to workmanship as it relates to mission success.
- Discuss planned additional component, functional, or static testing.
- Status and plans of remaining manufacturing and assembly.
- Discuss the integrity of design.
  - Suitability of shape and fin style for mission
  - Proper use of materials in fins, bulkheads, and structural elements
  - Proper assembly procedures, proper attachment and alignment of elements, solid connection points, and load paths
  - Sufficient motor mounting and retention
  - Status of verification
  - Drawings of the launch vehicle, subsystems, and major components
  - Include a Mass Statement. Discuss the estimated mass of the final design and its subsystems and components. Discuss the basis and accuracy of the mass estimate, the expected mass growth between CDR and the delivery of the final product, and the sensitivity of the launch vehicle to mass growth (e.g., How much mass margin there is before the vehicle becomes too heavy to launch on the selected propulsion system?).
- Discuss the safety and failure analysis.

#### **Subscale Flight Results**

- Include actual flight data from onboard computers, if available.
- Compare the predicted flight model to the actual flight data. Discuss the results.
- Discuss how the subscale flight data has impacted the design of the full-scale launch vehicle.

#### **Recovery Subsystem**

- Describe the parachute, harnesses, bulkheads, and attachment hardware.
- Discuss the electrical components and how they will work together to safely recover the launch vehicle.
- Include drawings/sketches, block diagrams, and electrical schematics.
- Discuss the kinetic energy at significant phases of the mission, especially at landing.
- Discuss test results.
- Discuss safety and failure analysis.

### **Mission Performance Predictions**

- State the mission performance criteria.
- Show flight profile simulations, altitude predictions with final vehicle design, weights, and actual motor thrust curve.
- Show thoroughness and validity of analysis, drag assessment, and scale modeling results.
- Show stability margin and the actual CP and CG relationship and locations.

### **Payload Integration**

Ease of integration

- Describe integration plan.
- Compatibility of elements.
- Simplicity of integration procedure.
- Discuss any changes in the payload resulting from the subscale test.

### **Launch concerns and operation procedures**

- Submit a draft of final assembly and launch procedures including:
  - Recovery preparation.
  - Motor preparation.
  - Setup on launcher.
  - Igniter installation.
  - Troubleshooting.
  - Post-flight inspection.

### **Safety and Environment (Vehicle and Payload)**

- Update the preliminary analysis of the failure modes of the proposed design of the rocket and payload integration and launch operations, including proposed, and completed mitigations.
- Update the listing of personnel hazards and data demonstrating that safety hazards have been researched, such as material safety data sheets, operator's manuals, and NAR regulations, and that hazard mitigations have been addressed and enacted.
- Discuss any environmental concerns.
  - This should include how the vehicle affects the environment, and how the environment can affect the vehicle.

## ***IV) Payload Criteria***

### **Testing and Design of Payload Equipment**

- Review the design at a system level.
  - Drawings and specifications
  - Analysis results
  - Test results
  - Integrity of design
- Demonstrate that the design can meet all system-level functional requirements.
- Specify approach to workmanship as it relates to mission success.
- Discuss planned component testing, functional testing, or static testing.
- Status and plans of remaining manufacturing and assembly.
- Describe integration plan.
- Discuss the precision of instrumentation and repeatability of measurement.

- Discuss the payload electronics with special attention given to safety switches and indicators.
  - Drawings and schematics
  - Block diagrams
  - Batteries/power
  - Switch and indicator wattage and location
  - Test plans
- Provide a safety and failure analysis.

### **Payload Concept Features and Definition**

- Creativity and originality
- Uniqueness or significance
- Suitable level of challenge

### **Science Value**

- Describe payload objectives.
- State the payload success criteria.
- Describe the experimental logic, approach, and method of investigation.
- Describe test and measurement, variables, and controls.
- Show relevance of expected data and accuracy/error analysis.
- Describe the experiment process procedures.

## ***V) Project Plan***

### **Show status of activities and schedule**

- Budget plan (in as much detail as possible)
- Funding plan
- Timeline (in as much detail as possible). GANTT charts are encouraged with a discussion and indication of the critical path. The critical path is the sequence of events that must occur before the next phase of the project can begin.
- Educational engagement plan and status

## ***VI) Conclusion***

# Critical Design Review Presentation

Please include the following information in your presentation:

- Final launch vehicle and payload dimensions
- Discuss key design features
- Final motor choice
- Rocket flight stability in static margin diagram
- Thrust-to-weight ratio and rail exit velocity
- Mass Statement and mass margin
- Parachute sizes, recovery harness type, size, length, and descent rates
- Kinetic energy at key phases of the mission, especially landing
- Predicted drift from the launch pad with 5-, 10-, 15-, and 20-mph wind
- Test plans and procedures
- Scale model flight test
- Tests of the staged recovery system
- Final payload design overview
- Payload integration
- Interfaces (internal within the launch vehicle and external to the ground)
- Status of requirements verification

The CDR will be presented to a panel that may be comprised of any combination of scientists, engineers, safety experts, education specialists, and industry partners. The team is expected to present and defend the final design of the launch vehicle (including the payload), showing that design meets the mission objectives and requirements and that the design can be safely constructed, tested, launched, and recovered. Upon successful completion of the CDR, the team is given the authority to proceed into the construction and verification phase of the life cycle, which will culminate in a Flight Readiness Review.

It is expected that the **team participants** deliver the report and answer all questions. The mentor shall only provide support in the presentation.

The presentation of the CDR shall be well prepared with a professional overall appearance. This includes, but is not limited to, the following: easy-to-see slides; appropriate placement of pictures, graphs, and videos; professional appearance of the presenters; speaking clearly and loudly; looking into the camera; referring to the slides, not reading them; and communicating to the panel in an appropriate and professional manner. The slides should be made with dark text on a light background.

# **Flight Readiness Review (FRR)**

## **Vehicle and Payload Experiment Criteria**

The FRR examines tests, demonstrations, analyses, and audits that determine the overall system (all projects working together) readiness for a safe and successful flight/launch and for subsequent flight operations of the as-built rocket and payload system. It also ensures that all flight and ground hardware, software, personnel, and procedures are operationally ready.

The panel will be expecting a professional and polished report. It is advised to follow the order of sections as they appear below.

### **Flight Readiness Review Report**

#### ***I) Summary of FRR report (1 page maximum)***

##### **Team Summary**

- Team name and mailing address
- Name of mentor, NAR/TRA number and certification level

##### **Launch Vehicle Summary**

- Size and mass
- Final motor choice
- Recovery system
- Rail size
- Milestone Review Flysheet

##### **Payload Summary**

- Payload title
- Summarize the payload
- Summarize experiment

#### ***II) Changes made since CDR (1-2 pages maximum)***

**Highlight all changes made since CDR and the reason for those changes.**

- Changes made to vehicle criteria
- Changes made to Payload criteria
- Changes made to project plan

#### ***III) Vehicle Criteria***

##### **Design and Construction of Vehicle**

- Describe the design and construction of the launch vehicle, with special attention to the features that will enable the vehicle to be launched and recovered safely.
  - Structural elements (such as airframe, fins, bulkheads, attachment hardware, etc.).
  - Electrical elements (wiring, switches, battery retention, retention of avionics boards, etc.).
  - Drawings and schematics to describe the assembly of the vehicle.

- Discuss flight reliability confidence. Demonstrate that the design can meet mission success criteria. Discuss analysis, and component, functional, or static testing.
- Present test data and discuss analysis, and component, functional, or static testing of components and subsystems.
- Describe the workmanship that will enable mission success.
- Provide a safety and failure analysis, including a table with failure modes, causes, effects, and risk mitigations.
- Discuss full-scale launch test results. Present and discuss actual flight data. Compare and contrast flight data to the predictions from analysis and simulations.
- Provide a Mass Report and the basis for the reported masses.

### **Recovery Subsystem**

- Describe and defend the robustness of as-built and as-tested recovery system.
  - Structural elements (such as bulkheads, harnesses, attachment hardware, etc.).
  - Electrical elements (such as altimeters/computers, switches, connectors).
  - Redundancy features.
  - Parachute sizes and descent rates
  - Drawings and schematics of the electrical and structural assemblies.
  - Rocket-locating transmitters with a discussion of frequency, wattage, and range.
  - Discuss the sensitivity of the recovery system to onboard devices that generate electromagnetic fields (such as transmitters). This topic should also be included in the Safety and Failure Analysis section.
- Suitable parachute size for mass, attachment scheme, deployment process, test results with ejection charge and electronics
- Safety and failure analysis. Include table with failure modes, causes, effects, and risk mitigations.

### **Mission Performance Predictions**

- State mission performance criteria.
- Provide flight profile simulations, altitude predictions with real vehicle data, component weights, and actual motor thrust curve. Include real values with optimized design for altitude. Include sensitivities.
- Thoroughness and validity of analysis, drag assessment, and scale modeling results. Compare analyses and simulations to measured values from ground and/or flight tests. Discuss how the predictive analyses and simulation have been made more accurate by test and flight data.
- Provide stability margin, with actual CP and CG relationship and locations. Include dimensional moment diagram or derivation of values with points indicated on vehicle. Include sensitivities.
- Discuss the management of kinetic energy through the various phases of the mission, with special attention to landing.
- Discuss the altitude of the launch vehicle and the drift of each independent section of the launch vehicle for winds of 0-, 5-, 10-, 15-, and 20-mph. It should be assumed that the rocket is launching in the same direction as the wind.

### **Verification (Vehicle)**

- For each requirement (in SOW), describe how that requirement has been satisfied and by what method the requirement was verified. Note: Design features of a product often satisfy requirements, and one or more of the following methods usually verify requirements: analysis, inspection, and test.
- The verification statement for each requirement should include results of the analysis, inspection, and/or test which prove that the requirement has been properly verified.



### **Safety and Environment (Vehicle)**

- Provide a safety and mission assurance analysis. Provide a Failure Modes and Effects Analysis (which can be as simple as a table of failure modes, causes, effects, and mitigations/controls put in place to minimize the occurrence or effect of the hazard or failure). Discuss likelihood and potential consequences for the top 5 to 10 failures (most likely to occur and/or worst consequences).
- As the program is moving into the operational phase of the Life Cycle, update the listing of personnel hazards, including data demonstrating that safety hazards that will still exist after FRR. Include a table, which discusses the remaining hazards, and the controls that have been put in place to minimize those safety hazards to the greatest extent possible.
- Discuss any environmental concerns that remain as the project moves into the operational phase of the life cycle.

### **Payload Integration**

- Describe the integration of the payload into the launch vehicle.
- Demonstrate compatibility of elements and show fit at interface dimensions.
- Describe and justify payload-housing integrity.
- Demonstrate integration: show a diagram of components and assembly with documented process.

## ***IV) Payload Criteria***

### **Experiment Concept**

This concerns the quality of science. Give clear, concise, and descriptive explanations.

- Creativity and originality
- Uniqueness or significance

### **Science Value**

- Describe payload objectives in a concise and distinct manner.
- State the mission success criteria.
- Describe the experimental logic, scientific approach, and method of investigation.
- Explain how it is a meaningful test and measurement, and explain variables and controls.
- Discuss the relevance of expected data, along with an accuracy/error analysis, including tables and plots
- Provide detailed experiment process procedures.

### **Payload Design**

- Describe the design and construction of the payload and demonstrate that the design meets all mission requirements.
  - Structural elements (such as airframe, bulkheads, attachment hardware, etc.).
  - Electrical elements (wiring, switches, battery retention, retention of avionics boards, etc.).
  - Drawings and schematics to describe the design and assembly of the payload.
- Provide information regarding the precision of instrumentation and repeatability of measurement (include calibration with uncertainty).
- Provide flight performance predictions (flight values integrated with detailed experiment operations).
- Specify approach to workmanship as it relates to mission success.
- Discuss the test and verification program.

## **Verification**

- For each payload requirement, describe how that requirement has been satisfied, and by what method the requirement was verified. Note: Design features often satisfy requirements, and one or more of the following methods usually verify requirements: analysis, inspection, and test.
- The verification statement for each payload requirement should include results of the analysis, inspection, and/or test which prove that the requirement has been properly verified.

## **Safety and Environment (payload)**

This will describe all concerns, research, and solutions to safety issues related to the payload.

- Provide a safety and mission assurance analysis. Provide a Failure Modes and Effects Analysis (which can be as simple as a table of failure modes, causes, effects, and mitigations/controls put in place to minimize the occurrence or effect of the hazard or failure). Discuss likelihood and potential consequences for the top 5 to 10 failures (most likely to occur and/or worst consequences).
- As the program is moving into the operational phase of the Life Cycle, update the listing of personnel hazards, including data demonstrating that safety hazards that will still exist after FRR. Include a table, which discusses the remaining hazards, and the controls that have been put in place to minimize those safety hazards to the greatest extent possible.
- Discuss any environmental concerns that still exist.

## ***V) Launch Operations Procedures***

### **Checklist**

Provide detailed procedure and check lists for the following (as a minimum).

- Recovery preparation
- Motor preparation
- Setup on launcher
- Igniter installation
- Launch procedure
- Troubleshooting
- Post-flight inspection

### **Safety and Quality Assurance**

Provide detailed safety procedures for each of the categories in the Launch Operations Procedures checklist.

Include the following:

- Provide data demonstrating that risks are at acceptable levels.
- Provide risk assessment for the launch operations, including proposed and completed mitigations.
- Discuss environmental concerns.
- Identify the individual that is responsible for maintaining safety, quality and procedures checklists.

## ***VI) Project Plan***

### **Show status of activities and schedule**

- Budget plan (in as much detail as possible)
- Funding plan
- Timeline (in as much detail as possible). GANTT charts are encouraged with a discussion and indication of the critical path. The critical path is the sequence of events that must occur before the next phase of the project can begin.
- Educational Engagement plan and status

## ***VII) Conclusion***

# Flight Readiness Review Presentation

Please include the following information in your presentation:

- Launch Vehicle and payload design and dimensions
- Discuss key design features of the launch vehicle
- Motor description
- Rocket flight stability in static margin diagram
- Launch thrust-to-weight ratio and rail exit velocity
- Mass statement
- Parachute sizes and descent rates
- Kinetic energy at key phases of the mission, especially at landing
- Predicted altitude of the launch vehicle with a 5-, 10-, 15-, and 20-mph wind
- Predicted drift from the launch pad with a 5-, 10-, 15-, and 20-mph wind
- Test plans and procedures
- Full-scale flight test. Present and discuss the actual flight test data.
- Recovery system tests
- Summary of Requirements Verification (launch vehicle)
- Payload design and dimensions
- Key design features of the launch vehicle
- Payload integration
- Interfaces with ground systems
- Summary of requirements verification (payload)

The FRR will be presented to a panel that may be comprised of any combination of scientists, engineers, safety experts, education specialists, and industry partners. The team is expected to present and defend the as-built launch vehicle (including the payload), showing that the launch vehicle meets all requirements and mission objectives and that the design can be safely launched and recovered. Upon successful completion of the FRR, the team is given the authority to proceed into the Launch and Operational phases of the life cycle.

It is expected that the **team participants** deliver the report and answer all questions. The mentor shall only provide support in the presentation.

The presentation of the FRR shall be well prepared with a professional overall appearance. This includes, but is not limited to, the following: easy to see slides; appropriate placement of pictures, graphs, and videos; professional appearance of the presenters; speaking clearly and loudly; looking into the camera; referring to the slides, not reading them; and communicating to the panel in an appropriate and professional manner. The slides should be made with dark text on a light background.

## **Launch Readiness Review (LRR)**

### **Vehicle and Payload Experiment Criteria**

The Launch Readiness Review (LRR) will be held by NASA and the National Association of Rocketry (NAR), our launch services provider. These inspections are only open to team members and mentors. These names were submitted as part of your team list. All rockets/payloads will undergo a detailed, deconstructive, hands-on inspection. Your team should bring all components of the rocket and payload except for the motor, black powder, and e-matches. Be able to present: anchored flight predictions, anchored drift predictions (15 mph crosswind), procedures and checklists, and CP and CG with loaded motor marked on the airframe. The rockets will be assessed for structural, electrical integrity, and safety features. At a minimum, all teams should have:

- An airframe prepared for flight with the exception of energetic materials.
- Data from the previous flight.
- A list of any flight anomalies that occurred on the previous full-scale flight and the mitigation actions.
- A list of any changes to the airframe since the last flight.
- Flight simulations.
- Pre-flight checklist and Fly Sheet.
- 

A “punch list” will be generated for each team. Items identified on the punch list should be corrected and verified by launch services/NASA prior to launch day. A flight card will be provided to teams, to be completed and provided at the RSO booth on launch day.

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## **Post-Launch Assessment Review (PLAR)**

### **Vehicle and Payload Experiment Criteria**

The PLAR is an assessment of system in-flight performance.

The PLAR should include the following items at a minimum and be about 4-15 pages in length.

- Team name
- Motor used
- Brief payload description
- Vehicle Dimensions
- Altitude reached (Feet)
- Vehicle Summary
- Data analysis & results of vehicle
- Payload summary
- Data analysis & results of payload
- Scientific value
- Visual data observed
- Lessons learned
- Summary of overall experience (what you attempted to do versus the results and how you felt your results were; how valuable you felt the experience was)
- Educational Engagement summary
- Budget Summary

# Educational Engagement Form

Please complete and submit this form each time you host an educational engagement event.

(Return within 2 weeks of the event end date)

School/Organization name:

Date(s) of event:

Location of event:

## Instructions for participant count

**Education/Direct Interactions:** A count of participants in instructional, hands-on activities where participants engage in learning a STEM topic by actively participating in an activity. This includes instructor- led facilitation around an activity regardless of media (e.g. DLN, face-to-face, downlink.etc.). Example: Students learn about Newton's Laws through building and flying a rocket. **This type of interaction will count towards your requirement for the project.**

**Education/Indirect Interactions:** A count of participants engaged in learning a STEM topic through instructor-led facilitation or presentation. Example: Students learn about Newton's Laws through a PowerPoint presentation.

**Outreach/Direct Interaction:** A count of participants who do not necessarily learn a STEM topic, but are able to get a hands-on look at STEM hardware. For example, team does a presentation to students about their Student Launch project, brings their rocket and components to the event, and flies a rocket at the end of the presentation.

**Outreach/Indirect Interaction:** A count of participants that interact with the team. For example: The team sets up a display at the local museum during Science Night. Students come by and talk to the team about their project.

Grade level and number of participants: (If you are able to break down the participants into grade levels: PreK-4, 5-9, 10-12, and 12+, this will be helpful.)

Participant's Grade Level	Education		Outreach	
	Direct Interactions	Indirect Interactions	Direct Interactions	Indirect Interactions
K-4				
5-9				
10-12				
12+				
Educators (5-9)				
Educators (other)				

Are the participants with a special group/organization (i.e. Girl Scouts, 4-H, school)?      Y      N

If yes, what group/organization?

Briefly describe your activities with this group:

Did you conduct an evaluation? If so, what were the results?

Describe the comprehensive feedback received.



# Safety



# High Power Rocket Safety Code

## Provided by the National Association of Rocketry

1. **Certification.** I will only fly high power rockets or possess high power rocket motors that are within the scope of my user certification and required licensing.
2. **Materials.** I will use only lightweight materials such as paper, wood, rubber, plastic, fiberglass, or when necessary ductile metal, for the construction of my rocket.
3. **Motors.** I will use only certified, commercially made rocket motors, and will not tamper with these motors or use them for any purposes except those recommended by the manufacturer. I will not allow smoking, open flames, nor heat sources within 25 feet of these motors.
4. **Ignition System.** I will launch my rockets with an electrical launch system, and with electrical motor igniters that are installed in the motor only after my rocket is at the launch pad or in a designated prepping area. My launch system will have a safety interlock that is in series with the launch switch that is not installed until my rocket is ready for launch, and will use a launch switch that returns to the "off" position when released. The function of onboard energetics and firing circuits will be inhibited except when my rocket is in the launching position.
5. **Misfires.** If my rocket does not launch when I press the button of my electrical launch system, I will remove the launcher's safety interlock or disconnect its battery, and will wait 60 seconds after the last launch attempt before allowing anyone to approach the rocket.
6. **Launch Safety.** I will use a 5-second countdown before launch. I will ensure that a means is available to warn participants and spectators in the event of a problem. I will ensure that no person is closer to the launch pad than allowed by the accompanying Minimum Distance Table. When arming onboard energetics and firing circuits I will ensure that no person is at the pad except safety personnel and those required for arming and disarming operations. I will check the stability of my rocket before flight and will not fly it if it cannot be determined to be stable. When conducting a simultaneous launch of more than one high power rocket I will observe the additional requirements of NFPA 1127.
7. **Launcher.** I will launch my rocket from a stable device that provides rigid guidance until the rocket has attained a speed that ensures a stable flight, and that is pointed to within 20 degrees of vertical. If the wind speed exceeds 5 miles per hour I will use a launcher length that permits the rocket to attain a safe velocity before separation from the launcher. I will use a blast deflector to prevent the motor's exhaust from hitting the ground. I will ensure that dry grass is cleared around each launch pad in accordance with the accompanying Minimum Distance table, and will increase this distance by a factor of 1.5 and clear that area of all combustible material if the rocket motor being launched uses titanium sponge in the propellant.
8. **Size.** My rocket will not contain any combination of motors that total more than 40,960 N-sec (9,208 pound-seconds) of total impulse. My rocket will not weigh more at liftoff than one-third of the certified average thrust of the high power rocket motor(s) intended to be ignited at launch.
9. **Flight Safety.** I will not launch my rocket at targets, into clouds, near airplanes, nor on trajectories that take it directly over the heads of spectators or beyond the boundaries of the launch site, and will not put any flammable or explosive payload in my rocket. I will not launch my rockets if wind speeds exceed 20 miles per hour. I will comply with Federal Aviation Administration airspace regulations when flying, and will ensure that my rocket will not exceed any applicable altitude limit in effect at that launch site.
10. **Launch Site.** I will launch my rocket outdoors, in an open area where trees, power lines, occupied buildings, and persons not involved in the launch do not present a hazard, and that is at least as large on its smallest dimension as one-half of the maximum altitude to which rockets are allowed to be flown at that site or 1,500 feet, whichever is greater, or 1,000 feet for rockets with a combined total impulse of less than 160 N-sec, a total liftoff weight of less than 1,500 grams, and a maximum expected altitude of less than 610 meters (2,000 feet).

11. **Launcher Location.** My launcher will be 1,500 feet from any occupied building or from any public highway on which traffic flow exceeds 10 vehicles per hour, not including traffic flow related to the launch. It will also be no closer than the appropriate Minimum Personnel Distance from the accompanying table from any boundary of the launch site.
12. **Recovery System.** I will use a recovery system such as a parachute in my rocket so that all parts of my rocket return safely and undamaged and can be flown again, and I will use only flame-resistant or fireproof recovery system wadding in my rocket.
13. **Recovery Safety.** I will not attempt to recover my rocket from power lines, tall trees, or other dangerous places, fly it under conditions where it is likely to recover in spectator areas or outside the launch site, nor attempt to catch it as it approaches the ground.

## Minimum Distance Table

Installed Total Impulse (Newton-Seconds)	Equivalent High Power Motor Type	Minimum Diameter of Cleared Area (ft.)	Minimum Personnel Distance (ft.)	Minimum Personnel Distance (Complex Rocket) (ft.)
0 – 320.00	H or smaller	50	100	200
320.01 – 640.00	I	50	100	200
640.01 – 1,280.00	J	50	100	200
1,280.01 – 2,560.00	K	75	200	300
2,560.01 – 5,120.00	L	100	300	500
5,120.01 – 10,240.00	M	125	500	1,000
10,240.01 – 20,480.00	N	125	1,000	1,500
20,480.01 – 40,960.00	O	125	1,500	2,000

**Note: A Complex rocket is one that is multi-staged or that is propelled by two or more rocket motors**

Revision of July 2008

Provided by the National Association of Rocketry ([www.nar.org](http://www.nar.org))



# Related Documents



## USLI Competition Awards

Award:	Award Description:	Determined by:	When awarded:
Vehicle Design Award	Awarded to the team with the most creative and innovative overall vehicle design for their intended payload while still maximizing safety and efficiency.	USLI panel	Launch Week
Experiment Design Award	Awarded to the team with the most creative and innovative payload design while maximizing safety and science value.	USLI panel	Launch Week
Safety Award	Awarded to the team that demonstrates the highest level of safety according to the scoring rubric.	USLI panel	Launch Week
Project Review (PDR/CDR/FRR) Award	Awarded to the team that is viewed to have the best combination of written reviews and formal presentations	USLI panel	Launch Week
Educational Engagement Award	Awarded to the team that is determined to have best inspired the study of rocketry and other science, technology, engineering, and math (STEM) related topics in their community. This team not only presented a high number of activities to a large number of people, but also delivered quality activities to a wide range of audiences.	USLI panel	Launch Week
Web Design Award	Awarded to the team that has the best, most efficient Web site with all documentation posted on time.	USLI panel	Launch Week
Altitude Award	Awarded to the team that achieves the best altitude score according to the scoring rubric and requirement 1.2.	USLI panel	Launch Week
Best Looking Rocket	Awarded to the team that is judged by their peers to have the "Best Looking Rocket"	Peers	Launch Week
Best Team Spirit Award	Awarded to the team that is judged by their peers to display the "Best Team Spirit" on launch day.	Peers	Launch Week
Best Rocket Fair Display Award	Awarded to the team that is judged by their peers to display the "Best Team Spirit" on launch day.	Peers	Launch Week
Rookie Award	Awarded to the top overall rookie team using the same criteria as the Overall Winner Award. (Only given if the overall winner is not a rookie team).	USLI panel	May 11, 2016
Overall Winner	Awarded to the top overall team. Design reviews, outreach, Web site, safety, and a successful flight will all factor into the Overall Winner.	USLI panel	May 11, 2016



# NASA Project Life Cycle

Charles Pierce  
Deputy Chief, Spacecraft & Auxiliary  
Propulsion Systems Branch,  
NASA - Marshall Space Flight Center

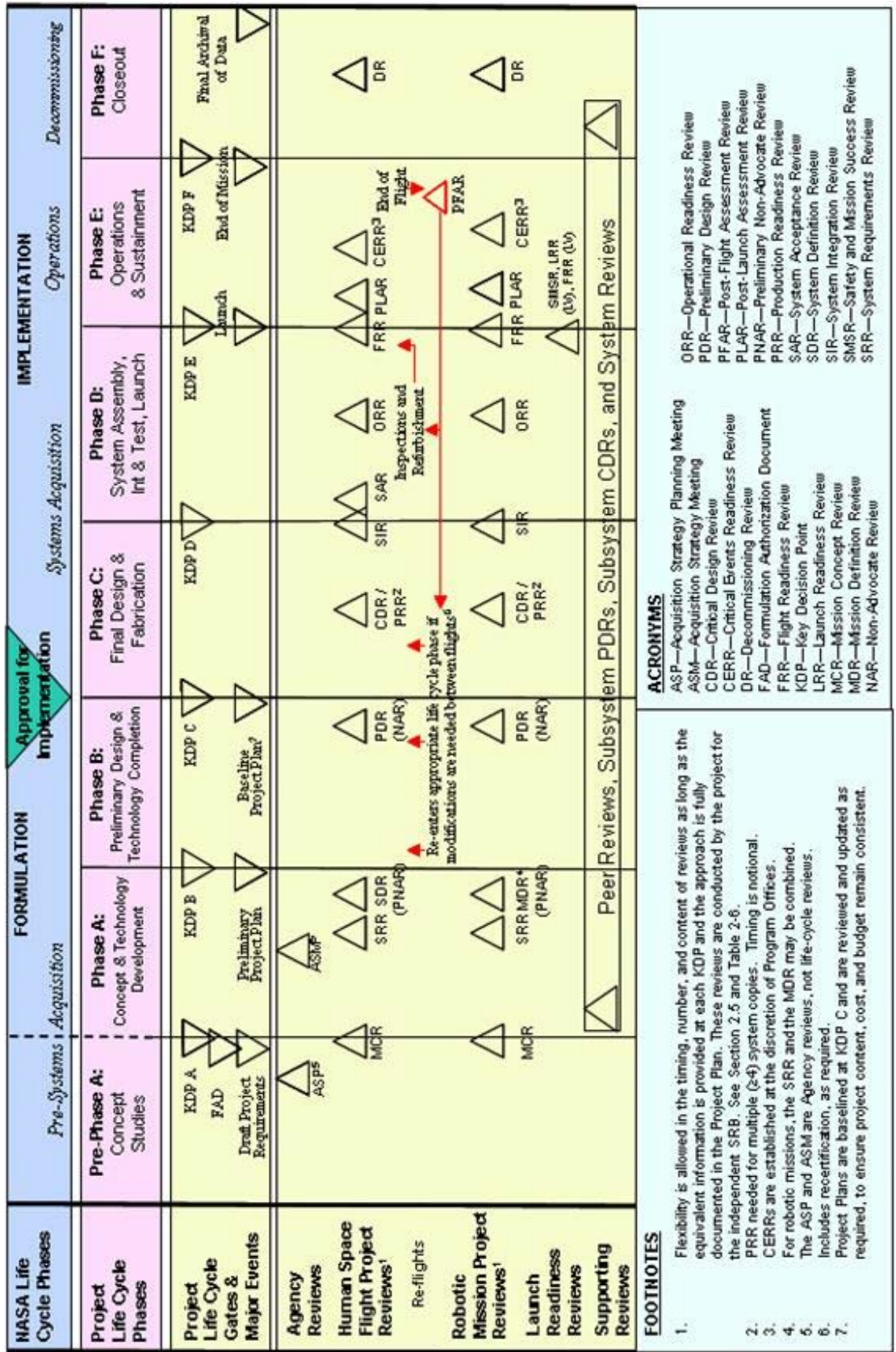
# Topics

- Purpose / Objective
- Project Life Cycle
- ~~System Requirements Review~~ (N/A to NASA Student Launch)
- Preliminary Design
- Critical (Final) Design
- Flight Readiness

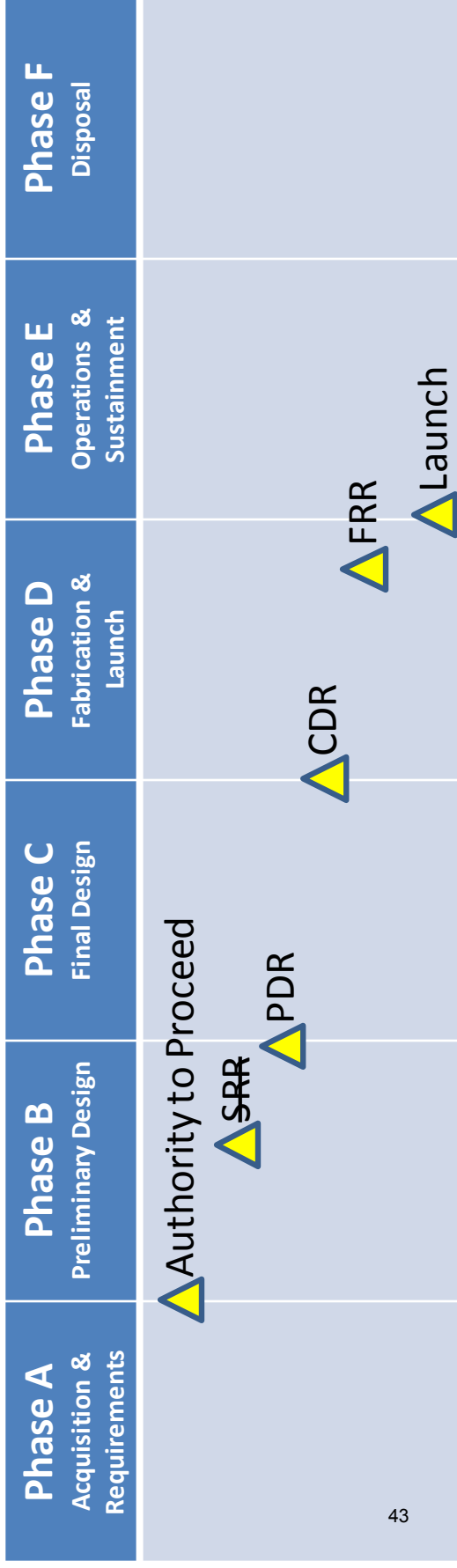
# Purpose/Objectives of the NASA Project Life Cycle

- Plan for the design, build, verification, flight operations, and disposal of the desired system
- Maintain consistency between projects
- Set expectations for Project Managers and System Engineers
  - Plans and Deliverables
  - Fidelity
  - Timing

# Typical NASA Project Life Cycle



# Student Launch Projects Life Cycle



- ATP (Authority to Proceed) – Funding is applied to the contract/effort and work performance can begin
- SRR (System Requirements Review) – Top Level Requirements are converted into system requirements. System Requirements are reviewed and authority is given to proceed into Preliminary Design. The NASA Student Launch Project skips this step.
- PDR (Preliminary Design Review) – Preliminary Design is reviewed and authority is given to proceed into Final Design.
- CDR (Critical Design Review) – Final Design is reviewed and authority is given to proceed to build the system.
- FRR (Flight Readiness Review) – As-built design and test data are reviewed and authority is given for Launch.

# Preliminary Design Review

- Objective
  - Prove the feasibility to build and launch the rocket/payload design.
  - Prove that all system requirements will be met.
  - Receive authority to proceed to the Final Design Phase
- Typical Products (Vehicle and Payload)
  - Schedule (design, build, test)
  - Cost/Budget Statement
  - Preliminary Design Discussion
    - Drawings, sketches
    - Identification and discussion of components
    - Analyses (such as Vehicle Trajectory Predictions)
    - Risks
    - Mass Statement and Mass Margin
  - Mission Profile (Concept of Operations)
  - Interfaces (within the system and external to the system)
  - Test and Verification Plan
  - Ground Support Equipment Designs/Identification
  - Safety Features



# Critical Design Review

- Objective
  - Complete the final design of the rocket/payload system
  - Receive authority to proceed into Fabrication and Verification phase
- Typical Products (Vehicle and Payload)
  - PDR Deliverables (matured to reflect the final design)
  - Report and discuss completed tests
  - Procedures and Checklists

# Flight Readiness Review

- Objective
  - Prove that the Rocket/Payload System has been fully built, tested, and verified to meet the system requirements
  - Prove that all system requirements have been, or will be, met
  - Receive authority to Launch
- Typical Products (Vehicle and Payload)
  - Schedule
  - Cost Statement
  - Design Overview
    - Key components
    - Key drawings and layouts
    - Trajectory and other key analyses
    - Mass Statement
    - Remaining Risks
  - Mission Profile
  - Presentation and analysis of test data
  - System Requirements Verification
  - Ground Support Equipment
  - Procedures and Check Lists

# Hazard Analysis

Introduction to managing Risk

# What is a Hazard?

Put simply, it's an outcome that will have an adverse affect on you, your project, or the environment. A classic example of a Hazard is a Fire or Explosion.

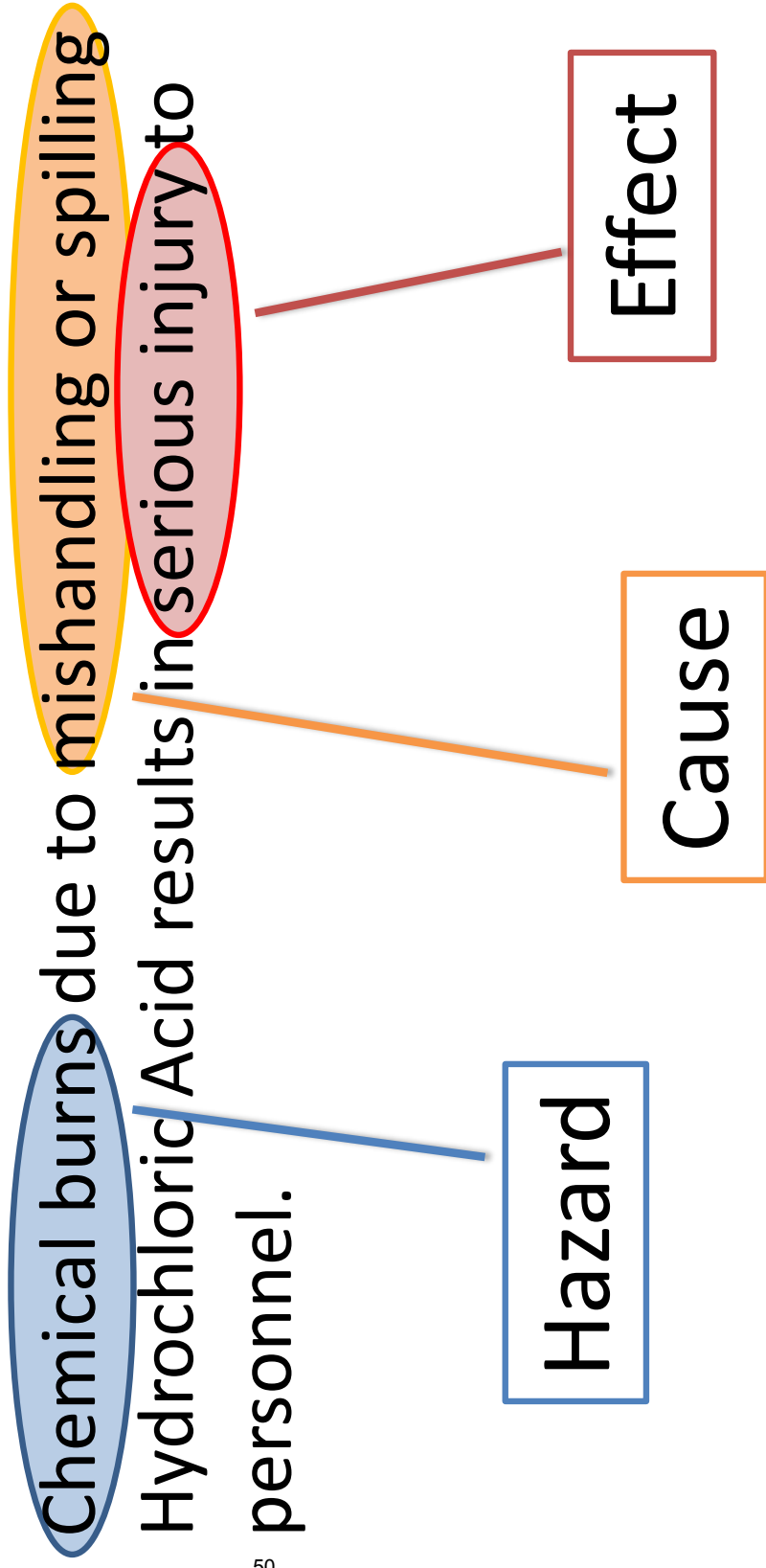
- A hazard has many parts, all of which play into how we categorize it, and how we respond.
- Not all hazards are life threatening or have catastrophic outcomes. They can be more benign, like cuts and bruises, funding issues, or schedule setbacks.

# Hazard Description

A hazard description is composed of 3 parts.

1. Hazard – Sometimes called the Hazardous event, or initiating event
2. Cause – How the Hazard occurs. Sometimes called the mechanism
3. Effect – The outcome. This is what you are worried about happening if the Hazard manifests.

# Example Hazard Description



# Risk

Risk is a measure of how much emphasis a hazard warrants.

Risk is defined by 2 factors:

- Likelihood – The chance that the hazard will occur. This is usually measured qualitatively but can be quantified if data exists.
- Severity – If the hazard occurs, how bad will it be?



# Risk Matrix Example

(excerpt from NASA MPR 8715.15)

TABLE CH1.1 RAC				
Probability	Severity			
	1 Catastrophic	2 Critical	3 Marginal	4 Negligible
A – Frequent	1A	2A	3A	4A
B – Probable	1B	2B	3B	4B
C – Occasional	1C	2C	3C	4C
D – Remote	1D	2D	3D	4D
E – Improbable	1E	2E	3E	4E

Table CH1.2 RISK ACCEPTANCE AND MANAGEMENT APPROVAL LEVEL	
Severity-Probability	Acceptance Level/Approving Authority
High Risk	Unacceptable. Documented approval from the MSFC EMC or an equivalent level independent management committee.
Medium Risk	Undesirable. Documented approval from the facility/operation owner's Department/Laboratory/Office Manager or designee(s) or an equivalent level management committee.
Low Risk	Acceptable. Documented approval from the supervisor directly responsible for operating the facility or performing the operation.
Minimal Risk	Acceptable. Documented approval not required, but an informal review by the supervisor directly responsible for operation the facility or performing the operation is highly recommended. Use of a generic JHA posted on the SHE Web page is recommended, if a generic JHA has been developed.

# Risk Continued

Defining the risk on a matrix helps manage what hazards need additional work, and which are at an acceptable level.

Risk should be assessed before any controls or mitigating factors are considered AND after. Update risk as you implement your safety controls.

# Mitigations/Controls

Identifying risk isn't useful if you don't do things to fix it!

Controls/mitigations are the safety plans and modifications you make to reduce your risk.

Types of Controls:

- Design/Analysis/Test
- Procedures/Safety Plans
- PPE (Personal Protective Equipment)

# Verification

As you progress through the design review process, you will identify many ways to control your hazards. Eventually you will be required to “prove” that the controls you identify are valid. This can be analysis or calculations required to show you have structural integrity, procedures to launch your rocket, or tests to validate your models.

Verifications should be included in your reports as they become available. By FRR all verifications shall be identified.

# Example Hazard Analysis

In addition to this handbook, you will receive an example Hazard Analysis. The example uses a matrix format for displaying the Hazards analyzed. This is not required, but it typically makes organizing and updating your analysis easier.

# **Safety Assessment Report (Hazard Analysis)**

## **Hazard Analysis for the 12 ft Chamber IR Lamp Array - Foam Panel Ablation Testing**

Prepared by:  
Industrial Safety  
Bastion Technologies, Inc.  
for:  
Safety & Mission Assurance Directorate  
QD12 – Industrial Safety Branch  
George C. Marshall Space Flight Center

## RAC CLASSIFICATIONS

The following tables and charts explain the Risk Assessment Codes (RACs) used to evaluate the hazards indentified in this report. RACs are established for both the initial hazard, that is; before controls have been applied, and the residual/remaining risk that remains after the implementation of controls. Additionally, table 2 provides approval/acceptance levels for differing levels of remaining risk. In all cases individual workers should be advised of the risk for each undertaking.

TABLE 1 RAC				
Probability	Severity			
	1 Catastrophic	2 Critical	3 Marginal	4 Negligible
A – Frequent	1A	2A	3A	4A
B – Probable	1B	2B	3B	4B
C – Occasional	1C	2C	3C	4C
D – Remote	1D	2D	3D	4D
E - Improbable	1E	2E	3E	4E

TABLE 2 Level of Risk and Level of Management Approval	
Level of Risk	Level of Management Approval/Approving Authority
High Risk	Highly Undesirable. Documented approval from the MSFC EMC or an equivalent level independent management committee.
Moderate Risk	Undesirable. Documented approval from the facility/operation owner's Department/Laboratory/Office Manager or designee(s) or an equivalent level management committee.
Low Risk	Acceptable. Documented approval from the supervisor directly responsible for operating the facility or performing the operation.
Minimal Risk	Acceptable. Documented approval not required, but an informal review by the supervisor directly responsible for operating the facility or performing the operation is highly recommended. Use of a generic JHA posted on the SHE Webpage is recommended.



<b>TABLE 3 Severity Definitions – A condition that can cause:</b>			
<b>Description</b>	<b>Personnel Safety and Health</b>	<b>Facility/Equipment</b>	<b>Environmental</b>
1 – Catastrophic	Loss of life or a permanent-disabling injury.	Loss of facility, systems or associated hardware.	Irreversible severe environmental damage that violates law and regulation.
2 - Critical	Severe injury or occupational-related illness.	Major damage to facilities, systems, or equipment.	Reversible environmental damage causing a violation of law or regulation.
3 - Marginal	Minor injury or occupational-related illness.	Minor damage to facilities, systems, or equipment.	Mitigatable environmental damage without violation of law or regulation where restoration activities can be accomplished.
4 - Negligible	First aid injury or occupational-related illness.	Minimal damage to facility, systems, or equipment.	Minimal environmental damage not violating law or regulation.

<b>TABLE 4 Probability Definitions</b>		
<b>Description</b>	<b>Qualitative Definition</b>	<b>Quantitative Definition</b>
A - Frequent	High likelihood to occur immediately or expected to be continuously experienced.	Probability is $> 0.1$
B - Probable	Likely to occur to expected to occur frequently within time.	$0.1 \geq \text{Probability} > 0.01$
C - Occasional	Expected to occur several times or occasionally within time.	$0.01 \geq \text{Probability} > 0.001$
D - Remote	Unlikely to occur, but can be reasonably expected to occur at some point within time.	$0.001 \geq \text{Probability} > 0.000001$
E - Improbable	Very unlikely to occur and an occurrence is not expected to be experienced within time.	$0.000001 \geq \text{Probability}$

<b>Hazard</b>	<b>Cause</b>	<b>Effect</b>	<b>Pre-RAC</b>	<b>Mitigation</b>	<b>Verification</b>	<b>Post-RAC</b>
Personnel exposure to high voltage	Contact with energized lamp bank circuits	Death or severe personnel injury	IC	<ol style="list-style-type: none"> <li>During test operation, lamp banks will be energized only when no personnel are inside chamber.</li> <li>Door to chamber will be closed prior to energizing circuits</li> <li>TS300 access controls are in place for the test</li> </ol>	<ol style="list-style-type: none"> <li>304-TCP-016, Section 3.1.3 requires disabling heater electrical circuit before entering chamber</li> <li>Per 304-TCP-016, tests will only be performed under personal direction of Test Engineer</li> <li>Access controls for this test are included in 304-TCP-016. These include: <ul style="list-style-type: none"> <li>Lower East Test Area Gate #6 and Turn C6 Light to RED</li> <li>Lower East Test Area Gate #7 and Turn C7 Light to RED</li> <li>Lower East Test Area Gate #8 and Turn C8 Light to RED</li> <li>Verify all Government sponsored vehicles are clear of the area.</li> <li>Verify all non-Government sponsored vehicles are clear of the area.</li> <li>Make the following announcement: <ul style="list-style-type: none"> <li>“Attention all personnel, test operations are about to begin at TS300. The area is cleared for the Designated Crew Only and will remain until further notice.” (REPEAT)</li> </ul> </li> </ul> </li> </ol>	IE
Personnel exposure to an oxygen deficient environment	Entry into 12 ft chamber with unknown atmosphere	Death or severe personnel injury	IC	<ol style="list-style-type: none"> <li>Oxygen monitors are stationed inside chamber and chamber entryway</li> <li>Chamber air ventilator operated after each panel test to vent chamber</li> </ol>	<ol style="list-style-type: none"> <li>304-TCP-016 requires installation of the Test Article using “Test Panel Install/Removal Procedure.” This procedure requires use of a portable O2 monitor in the section entitled “Post Test Activities and Test Panel Removal,” Step 1.</li> <li>304-TCP-016, Section 3.1.22 requires Chamber Vent System to run for 3+ Minutes prior to entering the chamber to remove the panel.</li> </ol>	IE

Hazard	Cause	Effect	Pre-RAC	Mitigation	Verification	Post-RAC
				<p>3. Attendant will be posted outside chamber to monitor in-chamber activities, facilitate evacuation or rescue if required, and to restrict access to unauthorized personnel</p> <p>4. Fire Dept. to be notified that confined space entries are being made</p>	<p>3. "Test Panel Install/Removal Procedure," page 1, requires the use of existing METTS confined space entry procedures, which includes requirement for an attendant when entering the 12 ft vacuum chamber reference Confined Space Permit 0298.</p> <p>4. "Test Panel Install/Removal Procedure," page 1, requires the use of existing METTS confined space entry procedures, which includes requirement to notify the Fire Dept. prior to entering the 12 ft vacuum chamber. Reference Confined Space Permit 0298.</p>	
Personnel exposure to lamp thermal energy	<ul style="list-style-type: none"> <li>Proximity to lamps while energized</li> <li>Accidental contact with lamp or calibration plate while out</li> </ul>	Personnel burns requiring medical treatment	3C	<p>1. During test operation, lamp banks circuits will be energized only when no personnel are inside chamber.</p> <p>2. Door to chamber will closed prior to energizing circuits</p> <p>3. Designated personnel will wear leather gloves to handle calibration plate if required.</p>	<p>1. 304-TCP-016, Section 3.1.3 requires disabling heater electrical circuit before entering chamber</p> <p>2. Per 304-TCP-016, tests will only be performed under personal direction of Test Engineer</p> <p>3. 304-TCP-16, Section 1.4, Hazards and Controls, requires insulated gloves as required if hot items need to be handled.</p>	3E

Hazard	Cause	Effect	Pre-RAC	Mitigation	Verification	Post-RAC
Failure of pressure systems	Over-pressurization	<ul style="list-style-type: none"> <li>Personnel injury</li> <li>Equipment damage</li> </ul>	IC	<ol style="list-style-type: none"> <li>TS300 facility pressure systems are certified.</li> <li>Per ET10 test engineer, high purity air system will be used at &lt; 150 psig operating pressure, therefore certification not required.</li> <li>All non-certified test equipment is pneumatically pressure tested to 150% of Maximum Allowable Working Pressure (MAWP)</li> </ol>	<ol style="list-style-type: none"> <li>Per the MSFC Pressure Systems Reporting Tool (PSRT), facility systems have been recertified under TLWT-CERT-10-TS300-RR2002 until 3/3/2020. The certification includes Gaseous Helium, Gaseous Hydrogen, Gaseous Nitrogen, High Purity Air, Liquid Hydrogen and Liquid Nitrogen systems.</li> <li>304-TCP-016, Step 2.1.14, requires HOR-12-128, 2nd Stage HP Air HOR, to be Loaded to 75psig.</li> <li>See Pressure Test Report PTR-001455 (Appendix A). All non-certified equipment has a minimum factor of safety of 4:1.</li> </ol>	IE
Foam panel catches fire during testing	Test requires high heat with possibility of panel burning	Release of hazards materials into test chamber	IC	<ol style="list-style-type: none"> <li>Byproducts of combustion have been evaluated by Industrial Hygiene personnel and a ventilation requirement of 10 minutes with the chamber 300 cfm ventilation fan has been established. This will provide enough air changes so very little or no residual gasses or vapors remain.</li> </ol>	<ol style="list-style-type: none"> <li>A minimum ventilation of the chamber should the foam panel burn during or after testing has been established by procedure 304-TCP-016 which requires the minimum 10 minute ventilation before personnel are allowed to enter. Additionally, if any abnormalities are observed the Industrial Health representative will be called to perform additional air sampling before personnel entry.</li> </ol>	IE



# Understanding MSDS's

By: Jeff Mitchell  
MSFC Environmental Health

# What is an MSDS?

- A Material Safety Data Sheet (MSDS) is a document produced by a manufacturer of a particular chemical and is intended to give a comprehensive overview of how to safely work with or handle this chemical

# What is an MSDS?

- MSDS's do not have a standard format, but they are all required to have certain information per OSHA 29 CFR 1910.1200
- Manufacturers of chemicals fulfill the requirements of this OSHA standard in different ways



# Required data for MSDS's

- Identity of hazardous chemical
- Chemical and common names
- Physical and chemical characteristics
- Physical hazards
- Health hazards
- Routes of entry
- Exposure limits

# Required data for MSDS's (Cont.)

- Carcinogenicity
- Procedures for safe handling and use
- Control measures
- Emergency and First-aid procedures
- Date of last MSDS update
- Manufacturer's name, address, and phone number

# Important Agencies

- ACGIH
  - The American Conference of Governmental Industrial Hygienist develop and publish occupational exposure limits for many chemicals, these limits are called TLV's (Threshold Limit Values)

# Important Agencies (Cont.)

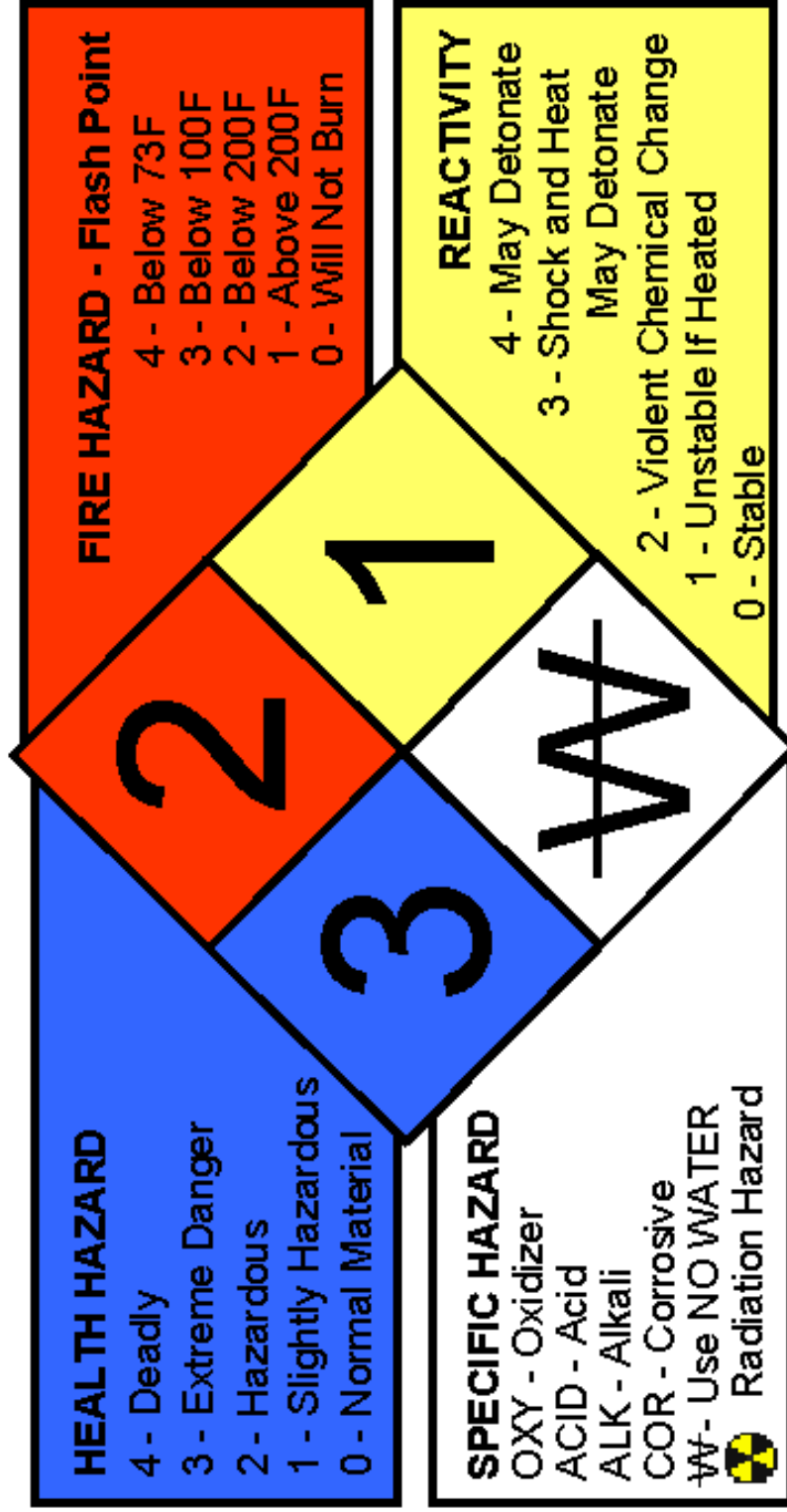
- ANSI
  - The American National Standards Institute is a private organization that identifies industrial and public national consensus standards that relate to safe design and performance of equipment and practices

# Important Agencies (Cont.)

- NFPA

- The National Fire Protection Association, among other things, established a rating system used on many labels of hazardous chemicals called the NFPA Diamond
- The NFPA Diamond gives concise information on the Health hazard, Flammability hazard, Reactivity hazard, and Special precautions
- An example of the NFPA Diamond is on the next slide

# NFPA Diamond



# Important Agencies (Cont.)

- NIOSH

- The National Institute of Occupational Safety and Health is an agency of the Public Health Service that tests and certifies respiratory and air sampling devices. It also investigates incidents and researches occupational safety



# Important Agencies (Cont.)

- OSHA

- The Occupational Safety and Health Administration is a Federal Agency with the mission to make sure that the safety and health concerns of all American workers are being met

# Exposure Limits

- Occupational exposure limits are set by different agencies
- Occupational exposure limits are designed to reflect a safe level of exposure
- Personnel exposure above the exposure limits is not considered safe

# Exposure Limits (Cont.)

- OSHA calls their exposure limits, PEL's, which stands for Permissible Exposure Limit
  - OSHA PEL's rarely change
- ACGIH, establishes TLV's, which stands for Threshold Limit Values
  - ACGIH TLV's are updated annually

# Exposure Limits (Cont.)

- A Ceiling limit (noted by C) is a concentration that shall never be exceeded at any time
- An IDLH atmosphere is one where the concentration of a chemical is high enough that it may be Immediately Dangerous to Life and Health

# Exposure Limits (Cont.)

- A STEL, is a Short Term Exposure Limit and is used to reflect a 15 minute exposure time
- A TWA, is a Time Weighted Average and is used to reflect an 8 hour exposure time

# Chemical and Physical Properties

- Boiling Point
  - The temperature at which the chemical changes from liquid phase to vapor phase
- Melting Point
  - The temperature at which the chemical changes from solid phase to liquid phase
- Vapor Pressure
  - The pressure of a vapor in equilibrium with its non-vapor phases. Most often the term is used to describe a liquid's tendency to evaporate
- Vapor Density
  - This is used to help determine if the vapor will rise or fall in air
- Viscosity
  - It is commonly perceived as "thickness", or resistance to pouring. A higher viscosity equals a thicker liquid

# Chemical and Physical Properties (Cont.)

- Specific Gravity
  - This is used to help determine if the liquid will float or sink in water
- Solubility
  - This is the amount of a solute that will dissolve in a specific solvent under given conditions
- Odor threshold
  - The lowest concentration at which most people may smell the chemical
- Flash point
  - The lowest temperature at which the chemical can form an ignitable mixture with air
- Upper (UEL) and lower explosive limits (LEL)
  - At concentrations in air below the LEL there is not enough fuel to continue an explosion; at concentrations above the UEL the fuel has displaced so much air that there is not enough oxygen to begin a reaction

# Things you should learn from MSDS's

- Is this chemical hazardous?
  - Read the Health Hazard section
- What will happen if I am exposed?
  - There is usually a section called Symptoms of Exposure under Health Hazard
- What should I do if I am overexposed?
  - Read Emergency and First-aid procedures
- How can I protect myself from exposure?
  - Read Routes of Entry, Procedures for safe handling and use, and Control measures



# Take your time!

- Since MSDS's don't have a standard format, what you are seeking may not be in the first place you look
- Study your MSDS's before there is a problem so you aren't rushed
- Read the entire MSDS, because information in one location may compliment information in another



The following slides are  
an abbreviated version  
of a real MSDS

Study it and become more  
familiar with this chemical

### SECTION 1. CHEMICAL PRODUCT AND COMPANY IDENTIFICATION

MDL INFORMATION SYSTEMS, INC.  
14600 CATALINA STREET  
1-800-635-0064 OR  
1-510-895-1313

FOR EMERGENCY SOURCE INFORMATION  
CONTACT: 1-615-366-2000 USA

CAS NUMBER: 78-93-3  
RTECS NUMBER: EL6475000  
EU NUMBER (EINECS):  
201-159-0  
EU INDEX NUMBER:  
606-002-00-3

Manufacturer name  
and phone #

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SUBSTANCE: METHYL ETHYL KETONE

TRADE NAMES/SYNONYMS:

BUTANONE; 2-BUTANONE; ETHYL METHYL KETONE; METHYL ACETONE; 3-BUTANONE; MEK;  
SCOTCH-GRIP ® BRAND SOLVENT #3 (3M); STOP, SHIELD, PEEL REDUCER (PYRAMID  
PLASTICS, INC.); STABOND C-THINNER (STABOND CORP.); OATEY CLEANER (OATEY  
COMPANY); RCRA U159; UN1193; STCC 4909243; C4H8O; OHS14460

Last revision

CHEMICAL FAMILY:  
Ketones, aliphatic

CREATION DATE: Sep 28 1984  
REVISION DATE: Mar 30 1997

## SECTION 2. COMPOSITION, INFORMATION ON INGREDIENTS

COMPONENT: METHYL ETHYL KETONE

CAS NUMBER: 78-93-3

PERCENTAGE: 100

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## SECTION 3. HAZARDS IDENTIFICATION

NFPA RATINGS (SCALE 0-4): Health=2 Fire=3 Reactivity=0

EMERGENCY OVERVIEW:

COLOR: colorless

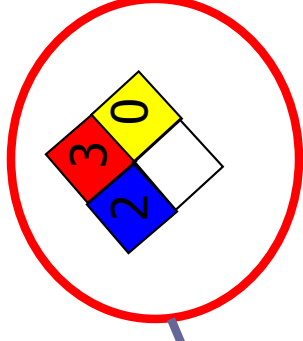
PHYSICAL FORM: liquid

ODOR: minty, sweet odor

MAJOR HEALTH HAZARDS: respiratory tract irritation, skin irritation, eye irritation, central nervous system depression

PHYSICAL HAZARDS: Flammable liquid and vapor. Vapor may cause flash fire

Good info for  
labeling containers



POTENTIAL HEALTH EFFECTS:  
INHALATION:

What happens when exposed?

SHORT TERM EXPOSURE: irritation, nausea, vomiting, difficulty breathing,

SKIN CONTACT:

SHORT TERM EXPOSURE: irritation

LONG TERM EXPOSURE: same as effects reported in short term exposure

EYE CONTACT...

INGESTION...

CARCINOGEN STATUS:

OSHA: N

NTP: N

IARC: N

Does it cause cancer?

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## SECTION 4. FIRST AID MEASURES

INHALATION...

SKIN CONTACT...

EYE CONTACT...

INGESTION...

What should you do if exposed?

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## SECTION 5. FIRE FIGHTING MEASURES

## SECTION 6. ACCIDENTAL RELEASE MEASURES

### AIR RELEASE:

Reduce vapors with water spray

### SOIL RELEASE:

Dig holding area such as lagoon, pond or pit for containment. Absorb with...

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## SECTION 7. HANDLING AND STORAGE

Store and handle in accordance ...

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## SECTION 8. EXPOSURE CONTROLS, PERSONAL PROTECTION

### EXPOSURE LIMITS:

#### METHYL ETHYL KETONE:

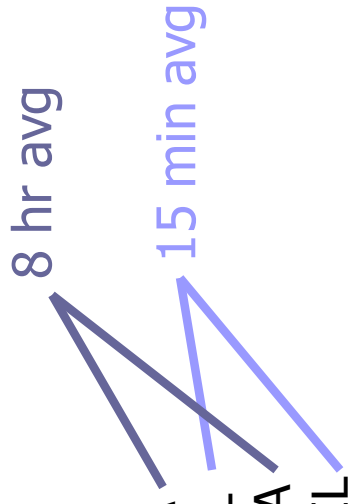
##### METHYL ETHYL KETONE:

200 ppm (590 mg/m<sup>3</sup>) OSHA TWA

300 ppm (885 mg/m<sup>3</sup>) OSHA STEL

200 ppm (590 mg/m<sup>3</sup>) ACGIH TWA

300 ppm (885 mg/m<sup>3</sup>) ACGIH STEL



## SECTION 9. PHYSICAL AND CHEMICAL PROPERTIES

COLOR: colorless

PHYSICAL FORM: liquid

ODOR: minty, sweet odor

MOLECULAR WEIGHT: 72.12

MOLECULAR FORMULA: C-H3-C-H2-C-O-C-H3

BOILING POINT: 176 F (80 C)

FREEZING POINT: -123 F (-86 C)

VAPOR PRESSURE: 100 mmHg @ 25 C

VAPOR DENSITY (air = 1): 2.5

SPECIFIC GRAVITY (water = 1): 0.8054

WATER SOLUBILITY: 27.5%

PH: No data available

VOLATILITY: No data available

ODOR THRESHOLD: 0.25-10 ppm

EVAPORATION RATE: 2.7 (ether = 1)

VISCOSITY: 0.40 cP @25 C

SOLVENT SOLUBILITY: alcohol, ether, benzene, acetone, oils, solvents

MYTH: if it smells bad it is harmful, if it smells good it is safe

MEK vapor is heavier than air

MEK liquid will float on stagnant water

Not very soluble in water

Will likely smell MEK before being overexposed

Goes to vapor easy

## SECTION 10. STABILITY AND REACTIVITY

## SECTION 11. TOXICOLOGICAL INFORMATION

MSDS's have an abundance of information useful in many different aspects

## SECTION 12. ECOLOGICAL INFORMATION

## SECTION 13. DISPOSAL CONSIDERATIONS

## SECTION 14. TRANSPORT INFORMATION

## SECTION 15. REGULATORY INFORMATION

## SECTION 16. OTHER INFORMATION





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**George C. Marshall Space Flight Center**

Huntsville, AL 35812

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